

Feasibility Study for Direct Utilization of
Geothermal Energy Resources at
Summerland, B.C.

RENEWABLE ENERGY BRANCH

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PREFACE

In response to a growing interest in development of geothermal resources at Summerland, B.C., Nevin Sadlier-Brown Goodbrand Ltd. (NSBG), on behalf of the Corporation of the District of Summerland, was contracted to investigate the feasibility of direct utilization of low temperature geothermal resources at Summerland, B.C. A comparatively high regional heat flow and the insulating effect of low thermal conductivity sediments within the Tertiary Summerland Basin create an environment where deeply circulating groundwater may be heated to economic temperatures. Based on a review of existing studies in the area, and collection and analysis of relevant energy parameters, the study identifies potential resource characteristics (such as temperature, flow rate, and production depth), and performs an economic evaluation of geothermal heating alternatives as they compare to conventional heating systems.

The current study arises from projects conducted throughout the region by Energy Mines & Resources Canada and by the B.C. Ministry of Energy Mines & Petroleum Resources during 1972 to 1985. Their work recognized the geothermal potential of numerous small sedimentary basins in south-central B.C. and encouraged further investigation of the resource. In support of development of alternative energy sources, Energy Mines & Resources Canada has funded a number of other studies at Summerland.

While the studies indicate encouraging potential for extraction of thermal fluids from the Summerland Basin, a feasibility study was required to more accurately define economic factors in development of the geothermal resource, and to determine the economic viability of production test drilling and the initiation of a geothermal demonstration heating project.

Although discussions are of a general nature, some of the topics covered in this study require a modest understanding of specialized engineering principles. Accordingly, some readers may wish to consult industry personnel for clarification of certain points.

Readers should also bear in mind that this study was undertaken using prevailing economic conditions at March, 1987. While price projections for items such as fuel and electricity have been incorporated into the economic model, recent swings in energy prices obviate the care with which price forecast should be reviewed. Also, for lack of data, a series of rather broad geological assumptions were cast in order to generate a number of geothermal resource parameters. While based on the best available current information, exploration may provide data which could significantly alter both the technical and economic viability of geothermal development.

ABSTRACT

A comparatively high regional heat flow and the insulating effect of low thermal conductivity volcanic and volcanoclastic sediments within the Summerland basin - situated in south-central B.C. - create an environment where deeply circulating groundwater may be heated to geothermally economic temperatures. From the limited data currently available, it is projected that resources at an estimated temperature of 55°C will be encountered at approximately 1000 m beneath potential application sites in the town of Summerland, and that the Basin could produce groundwater at rates as high as 10 L/s. Of the alternatives considered, water-well rotary equipment capable of drilling to the 1000 m target depth provides the most cost-effective means of obtaining geological data crucial to evaluation of the resource and extracting thermal fluids on a limited basis.

Economic analyses of two applications designed to utilize the low temperature resource indicate that either a small scale district heating plan or the heating of a large greenhouse complex could be a viable geothermal demonstration project. High benefit/cost ratios, particularly for such buildings as the Aquatic Centre and the greenhouses, lend support to recommendations proposing substantial expenditures on further investigation of geothermal resources at Summerland.



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EXECUTIVE SUMMARY

Because of its unique geological setting, Summerland - a rural community situated on the west bank of Okanagan Lake in B.C.'s southern interior - appears to be a good candidate for development and application of low temperature geothermal resources. The proximity of a number of application sites to the potential resource has sparked considerable interest in ongoing exploration for resources by both private and public interests in the Summerland area. The geothermal potential of the numerous related Tertiary outliers in south-central B.C., including the Summerland basin, was recognized in the early 1970's by Energy Mines and Resources Canada and the B.C. Ministry of Energy Mines and Petroleum Resources, both of whom have been instrumental in sponsoring ongoing studies in the region.

The current study arises from the necessity to determine the economic viability of continued geothermal exploration, and to provide the basis for a decision to be made regarding the initiation of a geothermal demonstration heating project. Geological and mechanical engineering disciplines were combined in order to assess the geothermal resource characteristics, to identify potential application sites and design a preliminary geothermal heating system, and finally to perform an economic analysis comparing geothermal and conventional or existing heating systems. Because exploration on the Summerland basin geothermal prospect is at a relatively early stage, engineering and economic modelling is contingent upon a variety of geological assumptions. Should exploration reveal conditions which vary significantly from these assumptions or if economic climates were to be substantially different from that currently prevailing, this report's conclusions should be viewed accordingly.

Geotechnical Evaluation

The Summerland basin is one of several Tertiary volcanic outliers located in the Okanagan area of south-central B.C. Rifting and graben development similar to that of the Basin and Range province of the southwestern U.S. occurred approximately 50 million years ago in response to major crustal extension during that time. Structural weaknesses at the intersection of the Summerland and Okanagan faults in the Summerland area probably allowed the intrusion of the volcanic rocks which form the base of the Summerland basin.

A comparatively high regional heat flow and the insulating effect of these low thermal conductivity volcanic sediments within the Summerland basin create an environment where deeply circulating groundwater may be heated to economic temperatures. It is hypothesized that groundwater descends along steeply dipping fault structures associated with the development of the Summerland basin, through deep permeable horizons within the volcanic sequence (where it is heated), and discharges by ascending permeable structures such as the Summerland fault.

It is estimated that geothermal resources would be intersected at approximately 1000 m, or that a sufficient number of permeable structures would be intersected within these 1,000 m to provide the required production capacity. The basin should have a reasonable chance of producing between 3 and 10 L/s of groundwater heated to temperatures between 50°C and 65°C.

In order to make efficient use of potential geothermal resources and because the location of application sites tightly constrains the positioning of a supply well, the next phase of investigation of Summerland's geothermal resources would involve deep exploration

drilling. The expense of drilling to the projected 1,000 m resource depth, and the limited knowledge of drilling conditions within the basin make a single well option the only viable production technique. This presumes that environmental constraints can be satisfied and surface disposal of geothermal fluids will be possible making drilling of a second well for re-injection unnecessary.

Because both exploration and production requirements must be addressed in the geothermal drilling program, the technique giving the most geological information, the greatest chance of completion, and that giving the capability to produce geothermal fluids on a small to medium scale for the least cost will be the most practical. Of three broad categories of drilling equipment, specialized water well drilling equipment capable of drilling to the 1000 m target depth appears to best fulfill these requirements. By comparison, drilling of large scale production holes using oil field rotary equipment would achieve a relatively high assurance of successful completion of the drilling program, but the high costs must be balanced against the risks of "dry hole". Diamond drill equipment is the least expensive option although the negative factors involved with this technique far outweigh the cost savings.

Artesian pressure conditions are not anticipated for a geothermal test production well drilled in the vicinity of the Summerland downtown area and as such, it will probably be necessary to install a downhole submersible pump within the well bore. Selection of a pump which does not itself make excessive energy demands and which will fit within a limited bore diameter constrained design of a production scenario to installation of a 50 HP pump at a depth of 150 to 200 m. It is essential that during production, the dynamic head level remain within

this depth range. Extraction techniques such as the installation of a downhole heat exchanger might be considered although at present, insufficient information regarding the nature of the Summerland geothermal resource makes evaluation of these alternatives difficult.

Deep groundwater analyses are currently unavailable for Summerland, but waters from other similar geological environments nearby contain no apparent toxic constituents. Precipitation of scale is also anticipated to be minimal as carbonate minerals would likely be undersaturated in the thermal waters. Discharge from geothermal production when diluted with surface water such as Trout Creek or Eneas Creek would probably meet both chemical and thermal environmental standards.

Applications Engineering

There are two general applications in which the heat from a geothermal well could be utilized; greenhouse heating and building heating. Water delivered at 55°C at a rate of 10 L/s was used for the basis of analysis of these applications, however the effects of obtaining water temperatures of 40°C and 80°C were investigated for the sake of comparison. The "most probable" scenario would be equivalent to a heat flow of approximately 1200 kW. Because there is a practical lower limit of 70°C for use of geothermal heat in cooling applications, this option has not been considered in this study.

In order to account for the extreme variability in building heating demand, geothermal heating systems were designed to provide for approximately 50% of the normal heating design and will account for 90% of the total demand for heat. As there is a limited supply of geothermal water and a significant cost associated with its pumping, the systems accommodate partial- rather than total-heating.

The study uses the "Net Present Value" (NPV) method for evaluating the alternatives considered, which discounts all future cash flows back to present day dollars. For this analysis it was assumed that the "real interest rate" would average 4%. Also, because the cost of energy is expected to increase at a rate greater than that of other goods and services, an "energy cost escalation rate" of 2% has been assumed. Finally, a 25-year period beyond which the investment retains no residual value was assumed. The combined effect of these factors is to yield a present value of \$19.23 for each dollar saved per year over a 25-year period.

Of the three large greenhouse facilities in the Summerland area, Mountain View Farms' 10,000 m² complex with an annual heating cost of approximately \$60,000 was considered to be the prime candidate for the application of geothermal heat in greenhouses and was used for developing costs contained in this study. The typical greenhouse is a modular structure covered in two layers of polyethylene plastic. Make-up air heating is accomplished through a gas-fired unit heater which maintains an optimum space temperature of approximately 18°C. Production efficiency is greatly increased by installation of a root level heating system typically consisting of coils of plastic tubing mounted on benches through which warm water is circulated. The heating system was designed to heat the buildings geothermally down to a 0°C outdoor temperature, with the existing heating system used to provide

supplemental heating. Each greenhouse module would have an air handling unit equipped with a heating coil designed to extract heat from the geothermal supply. Warm water passing through the coil would retain sufficient energy to supply the bench heating system without supplement from the existing boiler system. Should resource temperatures lower than the anticipated 55°C be encountered, a heat pump installation to boost the temperature of the water could be considered. The implementation of a geothermal heating system for the greenhouses would appear to be a sound economic investment.

The second application scenario, the central distribution system, was designed in order to make full use of heat from the modelled geothermal well. A number of candidates including the hospital, Giant's Head Elementary School, Farkdale Place Care Home and the Summerland Research Station, were excluded from the analysis at the outset because they were either too remote, or because the cost of retrofitting a geothermal distribution system to the facilities would be prohibitive.

The district heating system envisioned combines a well and associated pump house situated on the south side of the Aquatic Centre on publicly owned property and installation of a 75 mm insulated polybutylene underground pipeline running roughly eastward as far as the R.C.M.P. station. The estimated installed cost of the distribution pipe is approximately \$125.00/m of which approximately \$100.00/m is for excavation, placing the pipe, backfilling and repaving.

To assess whether individual buildings should be included within the geothermal distribution system, a billing cost was established and an evaluation made by comparing the potential energy cost savings with the building's retrofit costs. To amortize the initial cost of the well and distribution system and to cover operating costs, analysis places the billing rate at approximately \$0.39/m³. This represents a

cost of approximately \$3.31/gigajoule as compared to an adjusted cost of gas heat in Summerland of \$6.47/gigajoule.

As the first stage of preparation for this report, a survey of all major buildings in Summerland was performed. Of these, nine buildings as well as typical retail stores and residences, were analysed for current energy consumption and a preliminary design for a geothermal retrofit was made. Because of its relatively high demand for heating throughout most of the year, and heating of domestic hot water for showers, the Aquatic Centre is an excellent candidate for geothermal conversion. Outdoor air is brought into the building to control humidity build-up created by evaporation from the pool and must be heated to maintain the air temperature within the building. A geothermal heat system would include the installation of coils within the existing air handling units to provide the primary means of heating and the pre-heating of domestic hot water through the use of a heat exchanger.

Among other buildings investigated, both the library and museum were found to be readily adaptable to retrofitting to utilize geothermal heat. A conventional gas fired burner would be used to provide supplemental heat on colder days. The City Hall is currently heated with electricity and would require a completely new system if geothermal heat were to be used in this building. However, the intangible benefits of improved ventilation may be a factor in assessing the economics of a geothermal installation.

Analysis of the heating systems of both the high school and MacDonald Elementary School indicate that the present heating systems are not easily adapted for the use the low temperature water for heating. Any proposed system which utilizes geothermal heat would involve the

installation of a major amount of new heating and ventilating equipment.

The Recreation Centre was constructed with modern heating and ventilation systems which could be readily converted to use geothermal water by retrofitting with heating coils. The B.C. Fruit Packers facility is heated in a similar fashion although the costs of installing geothermal equipment may be prohibitive. The R.C.M.P. station, like typical home and retail buildings, is a relatively new single-storey building in good condition with heating and ventilation provided by gas-fired furnaces. Utilizing geothermal water to heat the building would involve the installation of heating coils in return air intakes for the furnace along with associated water distribution piping.

Overall analysis of the geothermal district heating scenario indicates positive net present values for geothermal conversion for all buildings except the schools. High benefit/cost ratios indicate that it would be to the community's advantage to invest in a heating system of this nature.

Geothermal exploration and development should proceed at Summerland using deep water well rotary drilling equipment. The siting of the well and selection of application sites will ultimately be determined by the nature and source of funding. As accurate engineering and cost data are obtained from the exploration program, it is essential that all aspects of the engineering design and economic analysis be reviewed and adjusted as necessary.

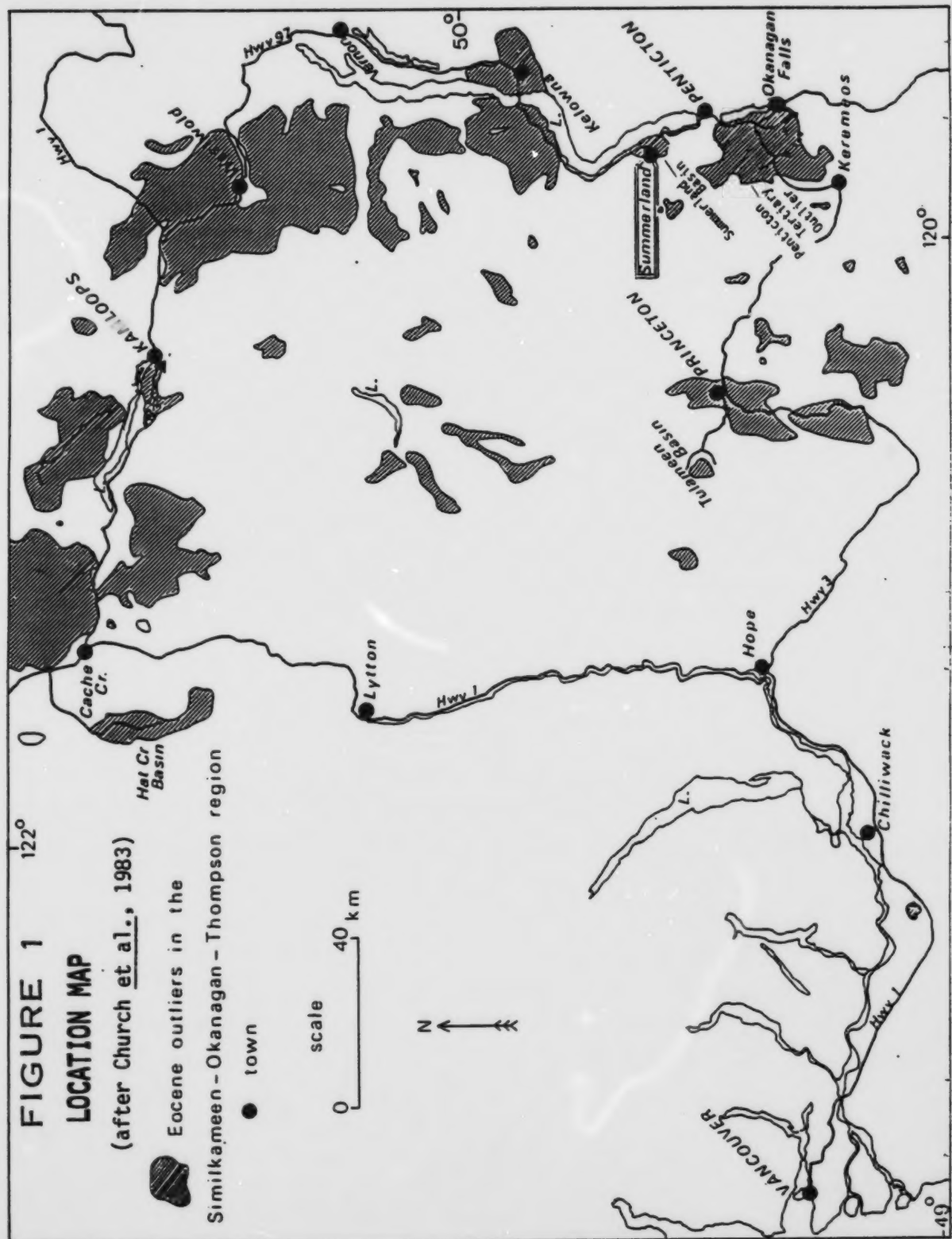
1. INTRODUCTION

Geothermal energy, that is the heat energy stored within the earth, is a vast, largely untapped alternate energy source. While relatively few localities worldwide have "high temperature" geothermal resources (greater than 150°C) suitable for power generation, unrecognized low temperature resources (20 to 90°C) adaptable to "direct use" applications are comparatively common.

Because of its unique geological setting, the Summerland area of south-central British Columbia appears to be one of good potential for development of low temperature geothermal resources. The proximity of a number of application sites to the potential resource has sparked considerable interest in on-going exploration for resources by both private and public interests in the Summerland area.

1.1 Community Background

The District of Summerland is a rural community situated on the west bank of Okanagan Lake in B.C.'s southern interior (Figure 1). The principal industry of the municipality of approximately 8,000 residents is agriculture with fruit being the main crop. A diversity of related industries has developed and includes a large tree-fruit packing and cold storage plant, fruit syrup, candy and jam manufacturing, an estate winery and three independent greenhouse operations. Agriculture Canada's Research Station at Summerland further augments the community's agricultural base, providing advanced facilities for scientists and technicians. Other local industries include a forest products plant milling dimensioned lumber and a truck canopy and camper manufacturing plant.



The municipality also provides two golf courses, racquet sports facilities, an indoor aquatic centre and a recreation centre housing ice arena, curling rink and banquet facilities. Health care, notably Senior Citizens' housing, is an integral part of the community, with Extended Care facilities at Summerland Hospital, and numerous Intermediate Care and Seniors' housing facilities throughout the community. Three elementary schools and one senior secondary school offer excellent facilities for all students.

The municipality administers its own electric utility system, purchasing power from West Kootenay Power & Light Company and distributing to Summerland ratepayers. It also maintains its own water utility system which supplies both residential water demands and irrigation to 1,500 hectares of farm land through a sophisticated pressure system.

1.2 Previous Work

Energy Mines & Resources Canada and the B.C. Ministry of Energy Mines & Petroleum Resources have been actively investigating the geothermal potential of the region since the early 1970's. At that time investigations by Church (1973) and Jessop and Judge (1971) suggested the geothermal potential of the White Lake basin and of numerous related Tertiary outliers in south-central B.C.

Drilling in the vicinity of the Summerland Basin was initiated by Lewis and Werner (1982), which to date, provides the only deep geological data on the area. Continued work by Davis and Lewis (1984) and Lewis (1984) confirmed a regional high heat flow and, combined with geological mapping by Church (1979b, 1980b), help to further develop the geothermal model of the Summerland Basin.

Since that time, Energy Mines & Resources have sponsored further studies into the geothermal potential of the Summerland Basin. Among the investigations are a preliminary analysis of heat loads for greenhouse and recreational complex at Summerland (Sworder, 1984), and a preliminary design and costing of a large diameter geothermal test well in the Summerland Basin (Sproule, 1984).

Piteau & Associates (1984) conducted a hydrogeological study of the Summerland Basin which assessed whether local recharge and deep groundwater flow would be adequate to support an exploitable low temperature geothermal resource. While the lack of firm geological data necessitated broad assumptions and comparisons with the analogous White Lake basin (Penticton Tertiary Outlier), the study concluded that a deep geothermal well should have a good prospect of encountering a sustained groundwater yield of 3 to 10 L/s.

The most recent activity in the investigation is the drilling of a slim diamond drill hole to approximately 200 m. With expenses partly funded by E.M.R., the "Mraz Well" was drilled on the contractor's property and data collected by Dr. T.J. Lewis. While difficulties in drilling necessitated abandonment of the well in the upper portion of the Basin sedimentary sequence, valuable geophysical and geological data were collected nonetheless.

1.3 Objectives

The current study arises from the necessity to determine the economic viability of continued geothermal exploration at Summerland Basin. Prior to the drilling of a deep test well it is important that the potential cost savings from geothermal energy alternatives be weighed against the price of conventional energy sources. The geotechnical studies are generally encouraging regarding the potential for extracting thermal fluids from the Basin, however a feasibility study is required to more accurately define geological factors affecting geothermal development and the scope of potential heating schemes, and to assess the numerous engineering aspects of geothermal utilization from an economic standpoint. The principal objective of this report is to provide the basis for a go/no go decision to be made on production test drilling and initiation of a geothermal demonstration heating project.

1.4 Method

The feasibility study combines geological and mechanical engineering disciplines in order to assess the viability of geothermal development at Summerland Basin. Of critical importance are the geothermal resource characteristics. A survey of existing data was used to evaluate critical parameters such as temperature, flow rate and depths of production. Based on these figures, a number of production well development scenarios were assessed. A market survey of equipment suppliers and contractors was conducted in order to evaluate the costs of producing the potential geothermal resource.

In order to assess the economic viability of conversion to geothermal energy, a number of potential application sites were selected and

heating system design and performance requirements were determined. The "applications engineering" task involved the collection of heating and energy requirements from a number of the geothermal conversion candidates within the downtown area. For each user, the cost of retrofitting or installation of new equipment and operation and maintenance costs were considered in development of a geothermal utilization scenario.

Finally, an economic analysis to compare geothermal with conventional or existing heating systems was performed in two utilization schemes; commercial greenhouse conversion and distribution to a number of centralized users within the commercial core of Summerland.

At this relatively early stage of exploration on the Summerland Basin geothermal prospect, it has been necessary to base an economic model on a variety of rather broad geological assumptions. For lack of firm geological data, assumptions regarding the temperature and depth of the geological resource, and the permeability and productivity of the host reservoir were made in order to evaluate the cost of resource development and production. Because geothermal development is strongly contingent upon success of the drilling program, a cost estimates to produce geothermal resources in unknown geological terrain are sensitive to variations of these assumptions. Wherever possible the reliance upon an exploration success has been mitigated by developing exploitation scenarios capable of utilizing a broad range of resource characteristics.

In the economic analysis, an energy pricing scenario considered most probable was used. However, the reader should be cautioned to consider that economic climates differing from that prevailing during March 1987 might have strong implications regarding the applicability of this report's conclusions.

2. GEOTECHNICAL EVALUATION

2.1 Regional Geological Setting

The Summerland Basin is one of several Tertiary volcanic outliers located the Okanagan area of south-central B.C. The Penticton Group is the name proposed by Church (1985) for a sequence of volcanic and sedimentary rocks found in the Kelowna, Summerland, Penticton and Rock Creek areas. The succession is part of a belt of Eocene volcanic and sedimentary rocks 100 km in width, extending 800 km northwestward from the Republic area of north-central Washington to the Babine Lake area in central B.C. (Church, 1985).

Volcanism in this "Intermontane belt" of central B.C. and coincidental major disturbances in the Rocky Mountains during the period 45 to 53 Ma corresponds with a northerly movement of the Pacific Plate. Church (1979b) suggests that "a complex inter-relationship of shears, tension faults, and folding could explain the simultaneous development of grabens and thrusting in the southern interior and eastern British Columbia". The regional north-south compressional forces during the Eocene produced a "herring bone" pattern of conjugate northwest and northeast trending shears. Rifting and graben development similar to that of the Basin and Range Province of the southwestern U.S. provided structural control on the development of the Tertiary outliers throughout southern B.C.

The type area for the Penticton Group is located in the Penticton Tertiary outlier (formerly "White Lake Basin"). Characteristically, basal sections of the outlier comprise sinuous valley-filling coarse

conglomeratic units derived from pre-Tertiary crystalline basement rocks. These are overlain by sheet-like lava and breccia deposits derived from fissure eruptions. Later (Miocene to Pliocene age) basalt flows commonly overlie the older, more felsic Eocene volcanic units. Volcaniclastic sediments deposited within the basins during periods of quiescence are interfingered within the sequence.

2.2 Geological Evolution of the Summerland Basin

Summerland basin is a small Tertiary outlier situated at the Okanagan city of Summerland. Church (1980b, p. 11) describes the basin as follows:

"The general structure, stratigraphy, and lithology of the Summerland basin seems to conform to the caldera model although only the central and western segments of this small Tertiary outlier have survived major faulting and erosion. The basin is obscured on the east by Okanagan Lake and truncated on the southeast by the Summerland fault (Fig. 2). Nevertheless, it retains a subcircular plan with beds dipping inward toward Giants Head which is a centrally located hill of relatively young Marama dacite lava, dated 48 Ma by K/Ar whole rock analysis."

As in the Penticton Tertiary outlier, the basal section of the Summerland basin comprises a coarse boulder conglomerate. The sequence probably represents valley filling alluvium and colluvium derived from the erosion of pre-Tertiary granitic basement rock underlying the succession. Because the formation will be limited in extent to paleovalleys and range-front talus accumulations, it has been referred to as a "shoestring" deposit. Exposures of the Kettle River Formation conglomerate and breccia are noted only on the extreme western edge of the basin (Figure 2).

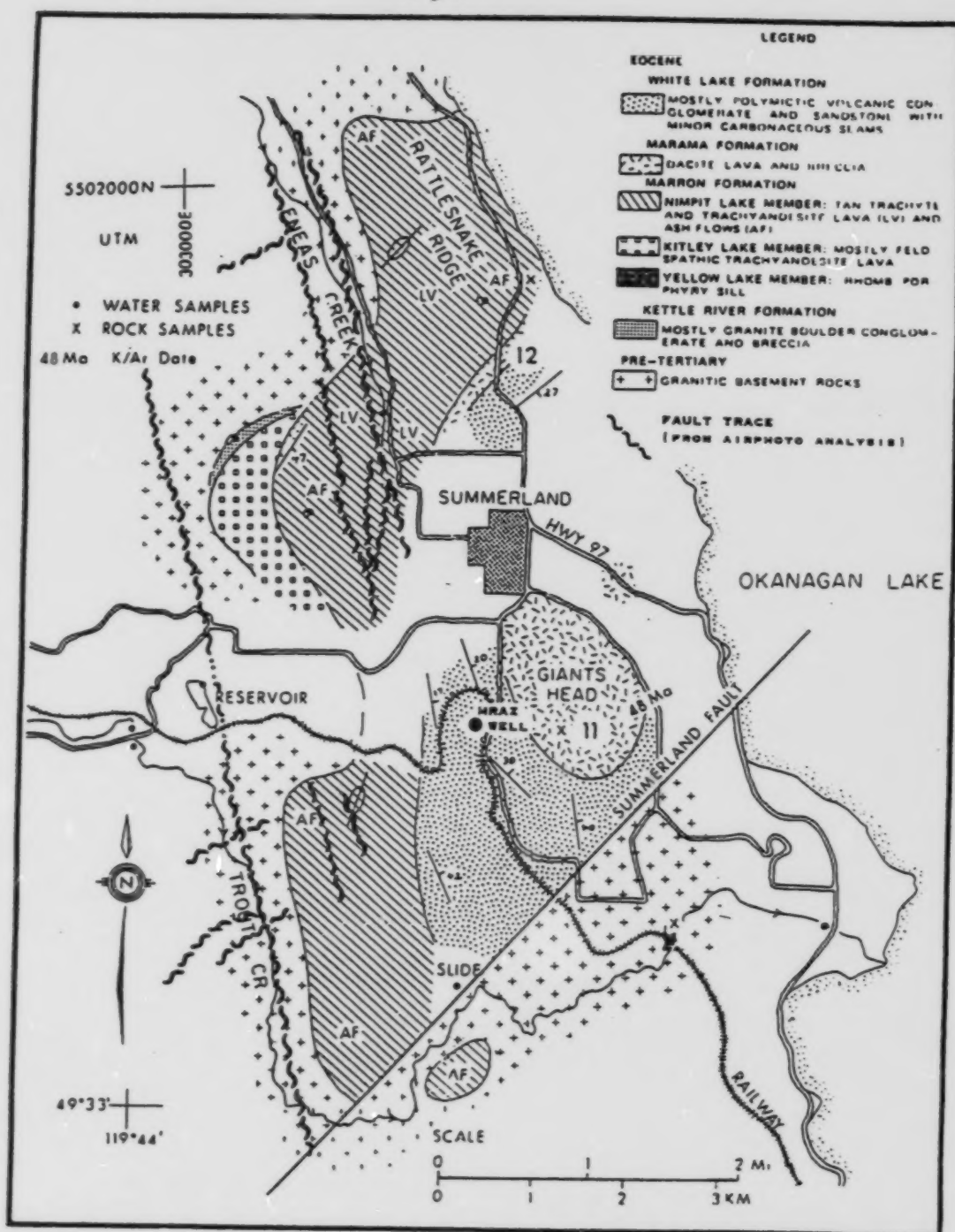


FIGURE 2

Geology of the Summerland caldera
 after Church (1980b)

Intense tectonic activity in the region signalled the first phase in the development of the basin. The structural weaknesses at the intersection of the Summerland and Okanagan faults in the Summerland area probably allowed intrusion of lavas forming the Kitley Lake member of the Marron Formation. Eruptions resulted in localized deposits of a feldspathic trachyandesite lava at the base of a large, rapidly developing topographic depression.

Discharge of the "Nimpit member" of the Marron Formation followed depositing as much as 1000 m of trachyte to trachyandesite lava and ashflows in the basin. It is the emplacement of this large volume of ashflows which provides the strongest support for the caldera collapse model proposed for the Summerland basin. Concentric normal faulting at the margins of the basin would result from caldera collapse. The Nimpit member probably erupted from a widespread series of fissures, also related to caldera collapse, and covered a broad area of the basin.

The Nimpit member lava and ashflows are succeeded by dacite lava and breccia of the Marama Formation. This later stage event involved the centralized intrusion of a progressively more viscous lava at the present day site of Giant's Head. Construction of the resurgent volcanic dome and occasional lava flows marked the completion of volcanism in the Summerland basin. Subsequent erosion of the dacite dome and deposition of 450 to 600 m of material into the "moat" surrounding Giant's Head formed a clastic sequence of polymictic volcanic conglomerate, sandstone, siltstone and shales which correlates with the sedimentary member of the White Lake Formation.

The northeast-southwest striking Summerland fault truncates the basin on its southeastern margin. The fault is considered to dip steeply northwestward. Movement on the fault appears to be normal although its linearity suggests some strike-slip component. Church (pers. comm.) describes a "trap door" movement of the Summerland basin fault block, with the "hinge" located some distance to the northwest of the map area. This partly accounts for the southeasterly dip of White Lake sediments (which would have been deposited sub-horizontally) in Highway 97 road cuts approximately 1 km north of Summerland. Much of the original structure of the basin is obscured by Quaternary deposits and erosion associated with regional glaciation.

Geothermal Model

In a suite of 20 measurements completed across south-central B.C., regionally high heat flows have been recorded in the south Okanagan by Davis & Lewis, 1984. In the immediate vicinity of the Summerland Basin, it is hypothesized that elevated temperatures may be encountered at comparatively shallow depths as a result of the insulating effect of the relatively low thermal conductivity volcanic and sedimentary rocks.

Permeable horizons within the volcanics such as gravel or conglomerate accumulated during quiescent periods between successive volcanic flows, or intense fracturing at the base and tops of volcanic sequences may represent suitable reservoirs for substantial volumes of water heated by the surrounding rock. It is hypothesized that groundwater circulates through these deep reservoirs by descending along steeply dipping fault structures associated with development of the Summerland caldera, and discharge by ascending permeable structures such as the Summerland Fault. While there has been no firm evidence for "leakage" of deeply circulating groundwaters in this vicinity, the thermal fluids may discharge directly into Okanagan Lake.

2.3 Resource Characteristics

The lack of deep (greater than 200 m) drilling within the Summerland basin precludes direct measurement of temperature characteristics in this immediate vicinity. However, heat flow measurements of approximately 85 mWm^{-2} have been calculated from a deep diamond drill hole in crystalline basement rock at Trout Creek canyon 1.5 km southeast of the margin of the Summerland Basin (Lewis & Werner, 1984). By using thermal conductivities based on values obtained from measurements on contemporaneous sediments in the Penticton Tertiary outlier, a geothermal gradient of 50 mK m^{-1} is estimated for the Summerland Basin. [That is, the temperature of the rock 1000 m beneath Summerland will be 50°C hotter than rock near surface.] While this technique may result in a slight overestimation of the geothermal gradient, the figure compares favourably with those from the Penticton Tertiary outlier, and suits the purpose of estimating temperatures beneath Summerland in the absence of other more definitive data.

Temperature, Depth and Groundwater Flow Patterns

The temperature of fluids and their distribution at depth is critically influenced by two geophysical processes. The first process assumes that the only heat transported through the system is that which enters at its base and leaves through the surface by natural conduction through rocks of the basin. Based on the 50 mK m^{-1} geothermal gradient, a preliminary estimate of temperatures of the basal rocks in the Summerland caldera is 55°C to 65°C . Temperatures will decrease upwards in a nearly linear pattern to surface where the rock will have a temperature of about 10°C .

The second process is convective heating in which circulating groundwater provides a heat transport mechanism capable of greatly distorting the thermal regime of the system. Surface water descending into the basin will have a cooling effect in recharge areas. Apparent geothermal gradients will be depressed, and higher resource temperatures will exist only at greater depth. Likewise, ascending thermal fluids will tend to heat the surrounding rock in discharge areas, resulting in apparently high geothermal gradients and more readily accessible, higher temperature fluids in lowland areas.

The depth of potential geothermal resources is also greatly influenced by geological and structural factors related to the evolution of the Summerland caldera. An air photo interpretation has identified two series of major north-northwesterly trending structural discontinuities in the Eneas and Trout Creek valleys (Figure 2). It is proposed that these are remnants of steeply dipping fissures and fault features associated with graben development in the Summerland Basin, and that these faults provide a hydraulic conduit for descending surface waters.

Once at depth, groundwater is considered to flow east-southeastward towards the Summerland fault, moving down-dip along permeable strata within the Summerland Basin succession. The Summerland fault both serves as a barrier to further southeastward groundwater flow and provides a permeable conduit for ascending thermal waters. Groundwater flow is probably deflected northeastward and discharges towards Okanagan Lake.

Although the groundwater discharge area at the "Perpetual Slide", located at the intersection of the Summerland fault and Trout Creek, is

probably an expression of shallow circulating waters infiltrating from irrigation of orchards on the high bench area, the pattern could be a reflection of deeper-circulating groundwaterflow. The shallow groundwater flow appears to discharge from the contact between the White Lake conglomerate and underlying Nimpit Lake ashflows where it intersects the Summerland fault. Although their geochemical signature suggests only shallow fluid circulation, a number of small swamps along the trace of the Summerland fault indicate that the area may be a discharge zone for fluids from the Summerland Basin. It should be noted that the "Mraz Well" experiences a small artesian pressure head, and further that preliminary logs suggest the well may have intersected the top of the Nimpit ashflows. At least on a shallow- to moderately-deep scale, this may support hypothesized southeastward groundwater flow along structural and stratigraphic components of the Summerland Basin, the existence of a discharge zone in the Summerland fault area, and the possibility of moderate to high groundwater pressure heads existing at depth within the basin.

For the purposes of this study, the depth of the target zone of the geothermal resources has been estimated at 1000 m. Geologically this represents an estimated depth to either the Kettle River formation conglomerate at the base of the succession or to interflows within the Nimpit Lake lavas and ashflows beneath major application sites in the vicinity of the Summerland downtown area. While the sequence may be thicker it is anticipated that a sufficient number of permeable structures would be intersected within these 1000 m to provide the required production capacity.

It is possible that thermal fluids may be intercepted at shallower depths as they ascend along permeable structures in discharge areas. However, for the application sites considered under this study, a scenario developing deeper thermal resources has been implemented (see Section 2.4). Beneath the "downtown" application sites, the groundwater flow path will likely have circulated to its greatest depth, and will have attained its warmest temperature which is anticipated to be 50°C to 65°C.

Flow Rate

The permeabilities of target aquifers in the Summerland Basin are likely to be fracture controlled. Piteau and Associates (1984) have estimated bulk hydraulic conductivity values at between 3×10^{-8} and 8×10^{-8} m/s. The probability that discreet zones of high permeability and groundwater flow similar to that encountered in the Penticton Teriarty outlier (Lewis, 1984) is considered good. However, the lack of firm hydrogeological data necessitated the use of these conservative values for the purposes of Piteau's groundwater modelling. The report concluded that a geothermal well drilled to the base of the Summerland Basin should have a reasonable chance of producing between 3 and 10 L/s of groundwater. If the well were pumped, groundwater flow would likely be induced from overlying strata and from surface waters, resulting in a substantial increase in sustained production of thermal water. However, after a year or so, production would decline to the base rate of between 3 and 10 L/s. Neglecting natural or induced recharge to the aquifer, production of thermal waters at a rate of 10 L/s could possibly be sustained for a period of up to five years. The Piteau study was conducted using a number of estimates and extrapolations and, as further exploration data becomes available, it is essential that actual hydraulic conductivities be determined and accurate basin yields be calculated.

Summary of Resource Parameters

For the purposes of economic modelling, three resource scenarios have been utilized as indicated in Table 1. As the critical component of the engineering calculations is the temperature of the resource, the three different scenarios reflect a variation only in this parameter. The "Most Probable" scenario is a reflection of resource characteristics considered most likely to be present in the Summerland Basin. "Optimistic" and "Pessimistic" scenarios were developed in order to demonstrate the sensitivity of temperature change on the economics of resource production. Decreasing "Depth" or increasing "Production Rate" values by a factor of two would have much the same effect on the economic model as identifying higher resource temperatures.

Table 1 - Estimated Geothermal Resource Parameters Summary

For Design and Analysis of Geothermal Development
Options at Summerland, B.C.

Scenario	Most Probable	Optimistic	Pessimistic
Temperature (°C)	55	80	40
Depth (m)	1000	1000	1000
Production Rate* (L/s [U.S.gal/min])	10(159)	10(159)	10(159)

*"Production Rate" refers to the rate at the Basin which could yield thermal fluids. While it is possible that artesian pressure conditions may be encountered, most probably, a geothermal well would require pumping to produce fluids at surface.

2.4 Resource Production

At the current level of understanding of Summerland's potential geothermal resources, the amount of energy likely to be gained from geothermal development does not justify large exploration expenditures. With the intention of demonstrating the viability of a small scale resource development project, the location of supply well sites is tightly constrained by their proximity to application sites. Because of localized high heat load users in the vicinity, a supply well in the downtown area of Summerland is likely to be the most logical site. A number of potentially good application sites in peripheral areas were investigated but were excluded from further analysis at the outset for both geological and economic reasons (see Section 5.1).

The next phase of investigation of Summerland's geothermal resources should involve deep exploration drilling. However, the nature of the resource suggests that any exploration success must be easily adapted to allow production of fluids. For instance, if warm water and sufficient permeabilities are encountered during drilling, the bore must be sufficiently large to accommodate a pump to supply the geothermal resource to surface.

Depth to the potential geothermal resource is the key parameter affecting supply well options. Not only will it affect the drilling technique selected to access the resource, it will ultimately determine costs of extracting the geothermal energy. The estimated depth of "intersection" with geothermal resources is 1000 m.

Single Well vs Field Well Production

Cost constraints introduced largely by the expense of drilling to a 1000 m deep resource, and the limited knowledge of drilling conditions within the Summerland basin currently make a single well option the only viable production technique. However, exploration plan contingencies which allow for shorter drill holes and multiple well sites should be implemented in the event that geothermal resources are encountered nearer surface.

It has been assumed that surface disposal of geothermal fluids will be possible. This assumption is contingent upon the fluids meeting environmental standards for conditions such as toxicity and temperature of the discharged geothermal water (see Section 2.5). No environmental problems related to fluid chemistry are anticipated. However, should a re-injection (disposal) well be required, additional costs on the order of those for the exploration wells could be anticipated. Certainly, surface disposal is far preferable economically if environmental constraints can be satisfied. This study has made no allowance for the drilling of a disposal well.

Well Supply Scenarios

The viability and relative merits of using oil field, water well and mineral industry drilling equipment are tabulated in Table 2. For drilling of large scale production holes to depths contemplated for Summerland, oil field rotary equipment is the most suitable. However, the relatively high assurance of a successful completion must be balanced against the risks of a "dry hole" or unsuccessful discovery

**COMPARISON OF RELATIVE MERITS OF
DIFFERING GEOTHERMAL DRILLING EQUIPMENT**

	OIL FIELD ROTARY	WATER WELL ROTARY	DIAMOND DRILL
1. Description	Standard oil field double	Moderate to deep Fayling rotary with stable foam circulation	Longyear 44 or equivalent with HQ collar NQ completion
2. Practical bore diameter for exploration purposes	7 5/8"	6 1/2"	2 1/2"
3. Practical depth limit	2000 m	1250 m	1250 m
4. Avg. penetration rate based on good "granite" drilling	4 m/hr	3.5 m/hr	2.5 m/hr
5. Estimated average drilling cost, exclusive of other requirements	\$135/m	\$75/m	\$90/m
6. Other required services	Extensive	Moderately extensive	Minimal
7. Total overall cost of drilling and completion program (See Tbl. 3, App A)	\$430,000	\$246,000	\$169,000
8. Probability of drilling program failure due to unforeseeable geological complications	Low	Moderately low to medium	High
9. Production capacity of completed well based only on diameter of well liner	Probably adequate for large scale demonstration project	Good for medium to small scale demonstration project	MAY be adequate if artesian conditions are encountered

NOTE THAT: Except in consideration of point 8, each technique has approximately the same chance for discovery, though none can assure it.

and the costs of obtaining a large diameter bore. Routine water well equipment is a viable alternative only if target depths are shallower than 300 m, although specialized rigs are capable of drilling to considerably greater depths. The option is also substantially less expensive than oil field equipment.

The least expensive option is mineral industry diamond drill equipment. While the technique gives excellent geological information, the likelihood that hot water production from a diamond drill well could be achieved is extremely small. The slim diameter of the well would preclude the installation of a downhole pump. Also, because of the comparatively sensitive nature of the drill equipment, geological conditions which might not otherwise affect other drilling techniques could result in the abandonment of a diamond drill hole.

Four single-well production scenarios have been costed in Appendix A and are summarized in Table 3. Each scenario is aimed at production from a depth of 1,000 m (or assumes that sufficient permeability will be intersected within these 1,000 m in order to provide required production capacity) and further assumes that the dynamic water level within the bore will be 150 m. In general, drilling costs reflect the size and complexity of the drilling equipment.

The stipulation that both exploration and production requirements be addressed in the next phase of geothermal development suggests that the well giving the most geological information, the greatest chance of completion, and that giving the capability to produce geothermal fluids on a small to medium scale for the least cost will be the most practical. Option 2 - the deep water well - appears to best fulfill

SUMMARY OF PRODUCTION WELL SCENARIOS AND COMPARATIVE COSTS

FOR 1000m* GEOTHERMAL WELL AT SUMMERLAND, B.C.

TABLE 3

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COSTS (CONTINGENCIES NOT INCLUDED)

OPTION	EQUIPMENT	DESCRIPTION	COSTS (CONTINGENCIES NOT INCLUDED)				COMMENTS
			DRILLING	COMPLETION	PRODUCTION	TOTAL	
1	Oil Field Rotary	Standard double equipment used in oil well drilling	\$302,000	\$ 53,000	\$ 76,000	\$ 431,000	- Cost is extremely sensitive to drilling delays and transportation expenses. - Risk of drilling program "failure" is low to medium.
2(a)	Water Well Rotary	"Fayling" deep rotary equipment with stable foam circulation	\$189,500	\$ 28,000	\$ 28,000	\$ 245,500	- Cost is moderately sensitive to drilling delays and transportation expenses. - Risk of drilling program "failure" is moderate.
(b)	Water Well Rotary	Same design as 2(a) though shortened to 500m total depth	\$160,000	\$ 13,500	\$ 28,000	\$201,500	- Design presumes geothermal resource is encountered nearer surface. - Drilling risk is substantially reduced over Option 2(a).
3	Diamond Drill	Longyear 44 or equivalent with HQ to 250m then HQ to 1000m	\$143,500	\$ 23,000	\$ 2,000	\$168,500	- Drilling technique is sensitive to difficult geological conditions and is considered very risky. - Diameter of well bore precludes production of thermal fluids unless resource is under artesian pressure.
4(a)	Diamond Drill/Water Well Rotary	Diamond drill hole of Option 3 reamed with water well rotary to 200m to accommodate down-hole pump	\$158,500	\$ 36,000	\$ 30,000	\$224,500	- Provides limited production capability to Option 3. - Most of risk is assumed in diamond drilling main hole but is still high.
(b)	Diamond Drill/Water Well Rotary	Same as 4(a) though shortened to 500m total depth	\$ 85,500	\$ 26,000	\$ 30,000	\$141,500	- Risk in diamond drilling phase is greatly reduced though production capacity remains limited by bore diameter.

* Except for Option 2(b) and 4(b)

these requirements. Specialized drilling and service contractors such as Air Drilling Services Ltd., of Nisku, Alberta, their affiliates, and more locally, Aquaterra Drilling Co., have proven geothermal expertise and have demonstrated considerable interest in the Summerland project. Option 2B could be implemented if geothermal resources are located at shallower depths.

Sensitivity

As drilling constitutes a major expense in the geothermal development process, due consideration should be given to the sensitivity of certain elements of the drilling program. Obviously, drilling costs are extremely sensitive to target depth. At 1000 m, incremental costs for diamond drilling increase rapidly while in this depth range, those for oil field equipment increase proportionately. Another sensitive depth consideration is the dynamic water level within the well bore. As costs for pump installation and operation will increase rapidly below this depth, alternatives such as downhole heat exchangers might be considered if lower dynamic water levels are experienced.

The most sensitive factors involved with deeper drilling using rotary equipment are transportation costs and rig rental rates. Because most of the equipment must be transported from oil field centres such as Calgary and Edmonton, prices for this equipment comprise a significant portion for trucking the equipment to and from the Summerland site. Costs could be significantly reduced if either local suppliers and drilling services could be found, or if the Prairie-based suppliers could move their equipment to B.C. at less expense.

Also, because of unknown geological conditions within the Summerland Basin, it is impossible to gauge the amount of time required to reach the resource target depth. While drilling could likely be completed within two weeks, unknown conditions at depth may cause significant drilling delays or possibly require premature well abandonment. Because of daily rental rates on the order of \$5,000 to \$6,000/day and delays in unfamiliar geological terrain are common, overruns must be considered a distinct possibility. Sproule (1984) suggests that "considering the distance [from supply centers] and unknown conditions at depth, we believe that a prudent operator would include a contingency allowance of 25-35%" in drilling cost estimates.

Production Options

An optimal geothermal production scenario would be one where artesian pressures brought the resource to surface without the expense of pumping. However, because of its location with respect to the regional groundwater flow regime, a geothermal test production well drilled in the vicinity of the Summerland downtown area would not be expected to produce thermal water without mechanical assistance. In developing resource production options, it has been essential to devise a scenario which allows installation of a downhole pump within a limited bore diameter, and to select a pump which does not itself make excessive energy demands.

The drilling options presented in Table 3 were designed with the intent of installing a 50 HP pump at a depth of 150 to 200 m. These constraints affect the size and cost of the downhole pump as well as the amount of energy required to power the pump. Costs for

installation, the physical size of the pump and its power requirements begin to increase rapidly below a depth of 150 m. It is important that during production, the well will have a dynamic head level within this depth range.

As an alternative to conventional pumping, installation of a downhole heat exchanger (D.H.E.) might be considered. The technique involves circulation of a "working" fluid through a closed loop installed within the bore hole, and has been successfully utilized in communities such as Klamath Falls, Oregon and Boise, Idaho. "Pumping" costs are substantially reduced because the fluid need only be circulated within the loop as compared to being "lifted" from the production level. A reduction in maintenance costs is another benefit of D.H.E.'s resulting from heat exchange equipment contacting only the secondary "working" fluid; not the commonly corrosive resource fluids. Operation of D.H.E.'s also mitigates environmental issues because no thermal fluids are extracted from the geothermal reservoir. While attractive from an environmental standpoint, the assumed depth of the resource, the cost of installing a large closed loop, and the numerous sensitive geological conditions required to make D.H.E. operation viable, place limitations on the suitability of the technique for installation at a demonstration stage at Summerland. However, the D.H.E. option might be given strong consideration as the body of knowledge on the resource increases.

Scaling problems, resulting primarily from precipitation of carbonate minerals on to distribution equipment such as heat exchangers, are commonly encountered with higher temperature geothermal fluids. Piteau (1984) anticipates that "scale forming minerals would likely be

undersaturated in the thermal waters". Again, as data on the geochemical nature of fluids from deep within the Summerland basin become available, corrosiveness, scaling potential and numerous other factors affecting equipment design and selection must be ascertained.

2.5 Environmental Concerns

Associated with the development of almost any natural resource are the costs of maintaining existing environmental standards. Environmental concerns confronting geothermal developers, particularly those with high temperature resources, have been thermal pollution and the disposal of large volumes of gas and water containing toxic components such as hydrogen sulfide, boron, arsenic and other heavy metals. However, for low temperature resources such as that envisioned at Summerland, environmental concerns are minimal because discharge temperatures and mineral content of the fluids are expected to be low.

For groundwaters from the analogous Penticton Tertiary outlier, Piteau (1984) noted that analyses showed no apparent toxic constituents, though drinking water standards for TDS, Na, Cl, SO_4 and F were exceeded. Discharge from geothermal production when diluted with surface waters such as Trout Creek or Eneas Creek would likely meet both chemical and thermal environmental standards. As analytical data on groundwater quality for samples from within the Summerland basin becomes available, it is essential that disposal options and requirements be reviewed.

3. APPLICATIONS IN GENERAL

3.1 Introduction

There are two general types of applications for the heat which could be obtained from a geothermal well; greenhouse heating and building heating.

Although both types of structures will use the heat in similar ways, there are constraints which make the two applications distinctly different. Greenhouses are usually clad with polyethylene plastic and are very light structures which are frequently disassembled. The system for a greenhouse therefore will have an emphasis on simplicity and low first cost. The building codes do not place constraints on the types of materials which may be used on greenhouses so inexpensive plastic pipe could be used.

Geothermal heat can be applied equally well to conventional buildings though building codes limit the use of such materials as plastic pipe. In Summerland, no one building is large enough to consume the full potential of the modelled geothermal well. The concept that is evaluated is a central distribution system to service major buildings in Summerland with an emphasis on publicly-owned buildings. The system includes a central geothermal well located in the vicinity of the Aquatic Centre with distribution piping running south on Kelly Avenue to Solly Road, east on Solly Road to Rosedale, north on Rosedale to Jubilee and east on Jubilee to B.C. Fruit Packers. Each building which uses the geothermal water would make a connection to the main similar to that of a conventional city water connection. The water would be metered as it entered the building and then distributed to air heating coils, radiation elements or heat exchangers so that the heat could be used be beneficially in the building.

Geothermal water has been used to provide cooling for many applications but the refrigeration equipment becomes very inefficient below 100°C geothermal water temperatures and, in practice, there is a lower limit of 70°C for practical use of geothermal heat for cooling. Since this is above the anticipated water temperature, cooling applications have not been considered in this study.

3.2 Available Heat

This analysis has assumed that 10 litres/second (l/s) of geothermal water flow would be available. The quantity of heat that this water produces is a function of the flow rate and the difference between the entering water temperature to the building and the leaving water temperature from the equipment that uses the heat. As discussed in Section 2.3, the most probable temperature for the water is 55°C. This temperature has been used as a basis for this analysis however the effects of obtaining water temperatures of 40°C and 80°C were analyzed and are reported herein.

Using generally available but specially selected equipment it is possible to cool the 55°C geothermal water to 27°C for discharging (28° temperature difference). With 40°C water, the discharge temperature of 23°C is possible (17° temperature difference). With 80°C water, it is possible to discharge the water at 30°C (50° temperature difference). Since the amount of heat withdrawn from the water is directly proportional to the temperature difference, the higher temperature water makes much better use of the available heat.

Using the above assumptions, the following heat flows are the maximum available:

40°C water - 700 kilowatts

55°C water - 1200 kilowatts

80°C water - 2100 kilowatts

One important characteristic of building heating is the extreme variability of the demand for heat. Typically, a building's heating system is designed to heat the building to the desired temperature not at the coldest recorded temperature but at a temperature, at which colder temperatures occur only 2.5% of the time in January, on average. For the Summerland/Penticton area, this temperature is -16°C. If the heating system were designed for a somewhat warmer temperature, then the system would heat the building satisfactorily for most of the year but an increased number of days in the year would have inadequate heating. This concept can be used beneficially to make the most effective use of a geothermal heating system. The following table outlines the demand for heat in various outdoor design temperatures.

Table 4.
Annual Heat Demand at Various Outdoor Temperatures

Design Temperature	Percentage of Normal Design Load	Degree Days Handled	Percentage of Annual Heat Demand
-16°C	100%	3556	100
-5°C	68%	3459	97%
0°C	53%	3269	92%
5°C	38%	2790	78%
10°C	24%	1959	55%

It can be seen from Table 4 that if the system is designed to handle outdoor temperatures down to -16°C , the system will handle 100% of the building heating. If the geothermal system were designed to handle the building heating at all outdoor temperatures above 10°C and an additional system were provided to provide the capacity beyond that temperature, the geothermal heat system would account for 55% of the annual heating demand. At an outdoor design temperature of 0°C , the geothermal heat system would account for 92% of the building's heat demand. As an approximation, if the geothermal heating system is designed for 50% of the normal heating design for the building, it will account for 90% of the total demand for heat. Because there is a limited supply of geothermal water and there is a significant cost associated with pumping that water, it is much better to design the system to accommodate partial heating, than to design the system to accommodate total heating. In effect, each gallon available will go twice as far to reduce energy costs in the community. Because of the above rationale, the retrofitted geothermal systems have been designed on the basis of 50% heating capacity where the existing heating system could be used to handle the remaining 50%. In some cases where there is minimal cost penalty, systems have been designed for 100% heating.

3.3 Economic Analysis

This study uses the "Net Present Value" (NPV) method for evaluating the alternatives considered. This method discounts all future cash flows back to present day dollars. If the discounted value of future dollar savings are greater than the initial investment, then the investment is worthwhile. The outcome of a NPV calculation is sensitive to the interest rates which are assumed. The most appropriate interest rate for private investment is the "real interest rate". This rate is the nominal rate (the rate available at lending institutions) less the expected annual inflation rate. For this analysis, it was assumed that the nominal interest rate is 10% and the annual inflation rate is 6% to give a real interest rate of 4%.

Another factor to be considered is the expected increase in the cost of energy relative to the cost of other goods and services. Oil and gas reserves are limited as is the provinces' ability to generate power by hydro-electric methods. These limitations will cause the cost of oil, gas and electricity to increase at a somewhat higher rate than will other goods and services. It was assumed for this study that this energy cost escalation rate is 2%. In other words, if we expect one dollar's worth of goods and services to cost \$1.06 next year, we would expect the cost of a dollar's worth oil, gas or electricity to cost \$1.08 next year.

The other factor to be considered for an economic analysis is the time period to be covered. For this study, a twenty-five year period was assumed with no residual value beyond that.

The combined effect of the four percent real interest rate, and the two percent energy cost escalation rate is to yield a present value of \$19.23 for a \$1.00 per year savings over twenty-five years. This factor is used for determining the present value of the future oil, gas or electricity costs. The present value of future costs for geothermal water uses the four percent real interest rate without the energy cost escalation rate. This assumption means that it is anticipated that the billing rate for geothermal water will increase over the years at a rate equal to the inflation rate only.

If the reader wishes to evaluate the effect of other real interest rates or energy cost escalation rates, the present values contained in the following table can be used to adjust the results of the System Analyses presented in Sections 4 and 5.

Table 5.

Present Value of \$1.00/year at Various Energy Escalation Rates

Real Interest Rates	25 Years			10 Years		
	No Escal.	4% Escal.	2% Escal.	No Escal.	4% Escal.	2% Escal.
10%	9.077	12.566	10.607	6.145	7.155	6.625
6%	12.783	18.943	15.444	7.360	8.672	7.983
4%	15.622†	24.038	19.229*	8.111	9.615	8.825
3%	17.413	27.322	21.644	8.530	10.144	9.295
2%	19.523	31.245	24.510	8.983	10.716	9.804

* Factor used to determine present value of conventional energy future costs.

† Factor used to determine present value of geothermal energy future costs.

4. GREENHOUSE APPLICATIONS

4.1 General

There are three large greenhouse facilities in the Summerland area:

- .1 Mountain View Farms - located on Washington Avenue;
- .2 Summerland Greenhouses - located on Canyon View Road; and
- .3 Deveron Nursery - located off Fosbery Road.

Mountain View Farms consists of greenhouses of approximately 10,000 m² in area, with annual heating cost of approximately \$60,000. These greenhouses are reasonably well located for the use of geothermal heat. They also have a significant heat demand which closely matches the output of a geothermal well. For these reasons, this greenhouse complex is considered a prime candidate for the application of geothermal heat and was used for developing costs contained in this study.

The Summerland Greenhouse facility is approximately 5,000 m² in area, however it does not appear to be well situated geologically for the use of geothermal heating. The heating cost of \$30,000 to \$35,000 per year for this facility is similar to that of Mountain View Farms, for the proportional area.

The third greenhouse facility, Deveron Nursery, is 5,000 m² in area and is a silvaculture facility. It has a substantially lower heating cost than the other greenhouse facilities with its heating cost at approximately \$6,000 per year. Although these are significant energy costs, the facility could not support a geothermal well on its own and it is too remote from the district heating system being considered for the other buildings.

4.2 Typical Greenhouses

The typical greenhouse is a modular structure covered in two layers of polyethylene plastic. A small fan pressurizes the space between the sheets to create an air space. The heat loss through the double layer of plastic is similar to that of conventional double glazing. Greenhouses require the introduction of some outdoor air to control the humidity within the space. This is usually accomplished through a gas-fired unit heater. Gas-fired heaters supply heat into the greenhouse as required to maintain the optimum space temperature of approximately 18°C. It has been found that production can be increased if a heating system is installed at the root level of the plants. This system typically consists of coils of plastic tubing on the benches through which warm (21°C. to 22°C.) water is circulated.

4.3 The Proposed Heating System

Because of very high heat demands in the greenhouse facility, it would be most appropriate that a partial geothermal heating system be implemented. The heating system would be designed to totally heat the buildings down to 0°C outdoor temperature. The existing heating system would be used to supplement the geothermal system to provide the additional heating required when outdoor temperatures are below 0°C.

The geothermal well would be located as centrally as possible in the greenhouse complex. Thermal water would be piped to each greenhouse through polybutylene pipe, a material which is relatively inexpensive and can withstand the anticipated water temperatures. The pipe would be uninsulated as it passes through the greenhouses, however the pipes located underground outdoors would be insulated with polyurethane insulation.

Each greenhouse module would have an air handling unit installed which contains a fan and a heating coil (Fan-coil unit). The air handling unit would be connected to the existing duct system and recirculate the air within each module. A control valve would control the flow of the geothermal water through the coil to provide control of the air temperature within the greenhouse. After the water has passed through the air handling unit's coil, the water will still contain sufficient heat to supply the bench heating system in total with no supplement from the existing boiler system.

The greenhouses can be heated directly using any of the anticipated geothermal water temperatures however the equipment cost is higher for the 40°C water.

If the water temperature is 40°C, a heat pump installation may be economic. A heat pump unit would be installed in each of the greenhouse modules to withdraw heat from the cooler geothermal water. Heat pumps, however, require increased use of electrical energy to drive the compressors in the units. The heat pump system would require only 4 l/s of geothermal water and consequently, a smaller well could be drilled at somewhat lower cost.

A summary of the costs of the installed systems, the expected annual operating costs and consequential savings in gas costs and the net present values are summarized in Table 6. Detailed breakdowns of the equipment cost estimates are contained in Appendix B.

Table 6.
Greenhouse Heating Equipment Costs and Operating Costs

	GEOTHERMAL WATER TEMPERATURES			
	40°C.	40°C.	55°C.	80°C.
	Alternate Number 1	Alternate Number 2		
Equipment Cost	\$220,000.	\$160,000.	\$163,000.	\$163,000.
Well Construction	\$246,000.	\$202,000.	\$246,000.	\$246,000.
Total Cost	\$466,000.	\$362,000.	\$409,000.	\$409,000.
Annual Operating Cost	\$ 4,000.	\$ 19,000.	\$ 3,000.	\$ 3,000.
Gas Cost Saved	\$ 44,000.	\$ 39,000.	\$ 55,000.	\$ 58,000.
Present Value of Operating Cost	\$ 62,000.	\$297,000.	\$ 47,000.	\$ 47,000.
Present Value of Fuel Savings	\$846,000.	\$750,000.	\$1,058,000.	\$1,115,000.
Net Present Value	\$318,000.	\$ 91,000.	\$602,000.	\$659,000.
Benefit/Cost Ratio	+ 0.68	+ 0.25	+ 1.47	+ 1.61

Alternate 1: Fan-Coil Units

Alternate 2: Heat Pump Units

4.4 Summary

As can be seen from Table 6, the installation of a geothermal heating system for the greenhouses has a positive net present value for all water temperatures. Using this criteria, the implementation of the geothermal heating system would be a good investment.

5. BUILDING APPLICATIONS

5.1 General

As the first stage of the preparation for this report, a survey of all the major buildings in Summerland was performed. The purpose of this survey was to evaluate the buildings to determine their adaptability for useage of geothermal heat. The buildings that were considered are:

Aquatic Centre	B.C. Fruit Packers' Facility
City Hall	Parkdale Place Care Home
Library	Giants' Head Elementary School
Museum	Summerland Research Station
High School	Typical Retail Stores
Recreation Centre	Typical Residences
Elementary School	R.C.M.P. Station
Hospital	

The hospital has a high demand for heat and geothermal heat could be applied to the building (particularly for domestic water heating). The hospital still would require the use of its steam boilers to provide steam for various functions within the hospital. An early decision was made that the hospital was too remote from the other buildings in the city to justify the cost of the distribution system to the hospital and therefore was subsequently excluded from the analysis.

The Giants' Head Elementary School has equipment which could be easily adaptable to geothermal heat however the remote location of the school relative to the city precludes an economic distribution of geothermal heat to the facility and therefore it also was excluded.

The Parkdale Place Care Home has a convenient location to the proposed distribution system however, the heating systems within the building are not easily adapted to the use of geothermal heat. An early decision was made that the cost of retrofitting geothermal to this facility would be prohibitive and therefore the use of geothermal heat would be not economic.

The Summerland Research Station is a large building with modern heating and ventilating systems which could easily be adapted for the use of geothermal heat. The building is, however, geologically not well located for a geothermal well. It is also too remote to pipe the geothermal water from a well in an optimal location. As a result, the building was excluded from the analysis.

5.2 Distribution

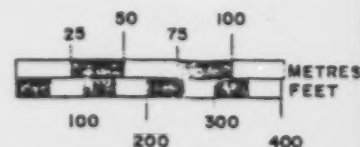
Figure 3 is a map of Summerland downtown area showing the location of buildings being considered for the use of geothermal heat.

Normally, the best location for the well and the associated pump house would be at the centroid of the heat demands which would minimize installed costs of the piping system as well as the pumping costs. For this analysis, it was assumed that the best location for the pump and well would be to the south side of the Aquatic Centre on publicly-owned property. This locates the well at one end of the distribution system rather than in the centre as would normally be the most efficient.



LEGEND:

- ROUTE OF DISTRIBUTION SYSTEM
- ===== ROUTE OF COMMERCIAL SYSTEM EXTENSION



DISTRICT OF SUMMERLAND PROPOSED GEOTHERMAL HEAT DISTRIBUTION SYSTEM

Reid Crowther & Partners Ltd.
Engineers • Planners • Scientists
Vancouver • Kelowna • Calgary • Red Deer
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**Reid
Crowther**

SCALE **AS NOTED**

DATE _____

DES _____ DWN _____

CKD _____ APP _____

PROJ. NO. **31026**

DWG. NO.

FIGURE -3

DATE	REVISIONS	APP

This, in fact, does not affect the piping costs because there is very little difference in the installed costs for the various piping sizes being considered. It was considered that all distribution piping under the street would be 75 mm. pipe.

The location selected allows an inexpensive expansion westward up Main Street to service any present and future commercial buildings along the street.

The distribution piping would be polybutylene pipe with polyurethane insulation and jacketting. This piping system could be purchased either pre-insulated in long sections for easy installation in trenches or be insulated and jacketted in the field prior to installation. The installed cost of the distribution pipe is approximately \$125.00 per metre which includes \$5.00 per metre for the polybutylene pipe; \$20.00 per metre for polyurethane insulation and \$100.00 per metre for excavation, placing the pipe, backfilling, and repaving. It would be recommended that when the supply pipe is installed in the trench, an uninsulated return pipe be installed as well. The cost of installing this extra pipe will be minimal but may be convenient for central disposing of the geothermal fluid rather than into the sewer system. Alternatively the warm water could be used beneficially for some other purpose.

An evaluation of whether the overall well system, distribution system, and heating installation in all buildings as a group is economic or not can easily be made using conventional economic analysis. These methods, however, will not determine whether it is economic to add any one building into the system or not. The most reasonable approach for individual building decisions is to establish a billing cost for the use of geothermal water and then to evaluate the potential net energy cost savings for the building against the building's retrofit costs.

5.3 Billing Rate

The procedure developed to establish a billing rate was to estimate the total annual demand for geothermal water in cubic metres (m^3) and relate that to the revenue needed per year to amortize the initial cost of the well and distribution system and to cover the operating costs. This analysis results in a cost per cubic metre for the geothermal water of \$0.41/ m^3 for 40°C water, \$0.39/ m^3 for 55°C water and \$0.45/ m^3 for 80°C water as calculated in Figure 4. These costs are not dramatically different but it should be remembered that 40°C water can yield 60% of the heat that 55°C water can and 80°C water can yield 168% of the heat that 55°C water can. The cost per gigajoule of energy is therefore significantly lower for the hotter water. The costs per gigajoule for the various temperatures are:

40°C water: \$ 4.45/GJ

55°C water: \$ 3.31/GJ

80°C water: \$ 2.27/GJ

The current cost of gas in Summerland is \$4.43/GJ for commercial use (5 to 99 GJ/month step). When adjusted for an average burner efficiency of 70%, the cost of heat produced by gas is \$6.47/GJ.

Figure 4
Calculation of Geothermal Billing Rate

Costs to be recovered:

Fixed Costs:

Well	\$ 256,000
Distribution System	<u>\$ 93,000</u>
	\$ 349,000

Amortize cost over 25 years at 4% real interest = \$ 22,000/year

Annual Costs:

Pump Energy	\$ 64,000
Maintenance	\$ 1,000
Meter Reading, Billing	<u>\$ 1,600</u>

\$ 9,000/year

Total Annual Revenue Required

\$ 31,000/year

	GEOTHERMAL WATER TEMPERATURE		
	40°C	55°C	80°C
Predicted Energy Consumption	7,100 GJ	9,300 GJ	13,300 GJ
Volume of Water Used	76,500/m ³	80,000/m ³	68,400/m ³
Rate to Recover Annual Costs	\$0.41/m ³	\$0.39/m ³	\$0.45/m ³

5.4 Buildings

.1 Aquatic Centre

The Aquatic Centre is an excellent application for geothermal heat. The building has a relatively high demand for heating throughout most of the year as well as a high demand for heating domestic water for showers.

The building has an air handling system which supplies outdoor air into the building to control the humidity build-up created by evaporation from the pool. As outdoor air is brought in, air must be heated to maintain the air temperature within the building.

A geothermal heat system would include the installation of coils within the existing air handling units to provide the primary means of heating. The geothermal water would be circulated through these coils by use of a circulating pump. The domestic hot water would be preheated by the geothermal water through the use of a heat exchanger. Water demand for showers has significant fluctuations throughout the day. The effect of these fluctuations would be minimized by the installation of an additional storage tank for the domestic water system (approximately 600 litres in size). An additional circulating pump would be provided to circulate the domestic water through the exchanger and into the storage tank.

The current heating costs of the swimming pool are approximately \$16,000 per year.

.2 City Hall

The City Hall presently does not have a ventilation system and is heated through the use of electric heat. A completely new heating system would be required if geothermal heat was to be used in this building.

If the geothermal water temperature were 40°C, water source heat pumps units could be installed. These package units would involve the installation of piping and ductwork off the units as well as electrical connections to each unit. A circulating pump would be required to circulate the water through all the units in the system. The use of this type of unit has the advantage that cooling is automatically provided for the building at minimal additional cost. The units would also provide air distribution to the space which is not currently ventilated. The conditions within the office therefore could be far superior to the existing conditions and although the economic analysis does not take this into account, it may be a factor in assessing the economics of an installation for the City Hall.

If the available geothermal water temperature is 55°C, fan coils could be installed which directly use the heat from the geothermal water to heat the building. The installed costs of such a system would be higher than that of the heat pump system as described above, however the operating costs will be much lower due to the minimal electrical energy required to run the fan coil units as compared to electrical energy required to run the heat pump units.

If the geothermal water temperature is 80°C, either the fan coil units as described above or simple baseboard heating elements could be installed to heat the building. The baseboard heating would be the most economic alternative.

.3 Library

The Library is heated through the use of a conventional gas furnace connected to the ductwork which distributes heat throughout the building.

This system could be easily retrofitted to utilize geothermal heat by the installation of a heating coil in the return air intake to the furnace. The geothermal water would be circulated through the coil on demand for heat. If the heat generated by the coil were not sufficient to heat the building, the burner in the furnace would automatically be activated.

.4 Museum

The museum's heating system is similar to the library however there are two rooftop air conditioning units provided.

The geothermal heating system would consist of heating coils being installed for each of the two air conditioning units. These coils would be connected to the geothermal heating system with the flow of the geothermal water through the coil being controlled on the demand for heating. If the heating coil cannot satisfy the heating demand, then the gas-fired burner of the air conditioner unit would be activated to provide the necessary boost in temperature.

.5 High School

The high school is 6400 m³ in area and has an estimated annual heating cost of \$17,000. This large building should be a good candidate for the use of geothermal heat however the present heating systems are

not easily adapted for the use of the low temperature water for heating. The existing systems are hot water radiation systems supplied by conventional hot water boilers. There are no ventilation systems for the classrooms into which the geothermal equipment could be retrofitted. Any proposed system which utilizes geothermal heat would involve the installation of a major amount of new heating and ventilating equipment.

For the use of 40°C geothermal water, three alternative heating systems were considered. The first alternative involved the use of unit ventilators in each classroom with high capacity coils capable of utilizing the 40°C water. These ventilators are the type of equipment which are commonly used in new schools. The units have a furniture finish indoor cabinet, a circulating fan, heating coils, filters and dampers to allow outdoor air to be introduced through the unit. The incorporation of these units into the school would provide an air quality control far superior to that which presently exists though the economic analysis does not take this into account. The owner may wish to consider this when evaluating the geothermal alternative.

The second alternative for the use of 40°C water is to utilize a heat pump system built into the unit ventilator. This feature substantially increases the cost of the unit ventilator however the consumption of geothermal water is reduced. The operating costs of this alternative are high because of the operating costs associated with running the heat pump.

The third alternative for the use of 40°C geothermal water is to use standard water source heat pumps. These units would be located in the corridor areas of the school with ductwork to supply air into the classrooms through sidewall registers. The installed costs of this alternative are the lowest of the three considered however there will be the electrical costs associated with operating the heat pump units.

The system considered for the use of 55°C geothermal water is the conventional unit ventilator system as described above. The system is slightly cheaper than the previous one because lower capacity coils can be used at this high water temperature.

Two alternatives were considered for the use of 80°C geothermal water. The first alternative was the application of the conventional unit ventilators, as described above. The second system alternative was the use of conventional cabinet convection heaters installed to supplement the existing heating system. This alternative could involve either the installation of new cabinets with fin-tube elements or the installation of additional roll of fin-tube elements within the existing cabinets in the school. This alternative will produce similar comfort conditions within the school as presently exist. The ventilation conditions would not be affected.

.6 Elementary School

MacDonald Elementary School is approximately 3600 m² in area and has two storeys plus a basement for the original half of the building. An Annex was added to the school around 1970 which was constructed to modern day standards.

The heating system for the original half of the building utilizes hot water convectors. The Annex area is heated by the use of five gas-fired furnaces. It is estimated that current heating costs for the school are \$10,000. per year.

The systems being considered for the older half of the building would be similar to those considered for the high school for 40°C water. Two alternatives were considered - unit ventilators and conventional water

source heat pump units. For 55°C water, unit ventilators were considered; for 80°C both unit ventilators and conventional supplementary convectors were considered. For all water temperatures heating coils would be installed for the return air duct to the five gas-fired furnaces.

.7 Recreation Centre

The recreation centre consists of 4,200 m² of curling and ice rink and 2,000 m² of additional support area on two floors. The building was constructed in 1975 with modern heating and ventilation systems. Other than the curling rink and ice rink area, the building is heated by gas-fired air handling units and unit heaters. There are two main air handling units supplying outdoor air into the facility with additional heat being provided by eight conventional unit heaters. There are four domestic hot water heaters to provide hot water for showers and other uses in the building. The annual cost of gas for heating the building has been \$13,000. It is estimated that of this amount, approximately \$10,000. is for building heating and \$3,000. is for domestic hot water heating.

In order to use geothermal water for heating the building, the two air handling units would be retrofitted with heating coils. The ten unit heaters would be supplemented by fan coil units with the provision of ductwork for distribution of the warm air.

.8 B.C. Fruit Packers

The B.C. Fruit Packers facility is a large light industrial fruit processing plant of approximately 6,000 m² in area. The building is single storey with concrete walls with a steel roof deck. The heating for the area is handled by a number of gas-fired unit heaters. The actual annual heating costs for the building was unavailable but was estimated to be approximately \$14,000.

To utilize geothermal water to heat the building, the existing gas-fired unit heaters would be supplemented by the addition of fan coil units. The number of fan coil units required would depend on the temperature of the geothermal water. Twelve fan-coil units would be provided if the geothermal water temperature is 40°C and nine if the water temperature is 55°C or higher.

An alternate of installing heat pump units instead of fan coil units for the 40°C water was also investigated. In this case, twenty heat pump units would be required. Although the installed costs of the heat pump system is less than the fan coil system, there is extra electrical costs associated with running the heat pump units and the initial premium cost of the fan coils would be quickly recovered.

.9 R.C.M.P. Station

The RCMP Station is relatively new single-storey building in good condition. Heating and ventilation are provided by three gas-fired furnaces, one of which supplies the garage.

Utilizing geothermal water to heat the building would involve the installation of heating coils in the return air intakes for each furnace along with associated water distribution piping. The actual gas cost for the building has been \$1,400. per year.

5.5 System Analysis

Tables 7, 8 and 9 summarize the estimated equipment costs, the anticipated operating costs, the fuel cost savings and the net present values for the various buildings considered.

From the tables, it can be seen that it is not economic to connect the two schools to the geothermal system unless the benefits gained from the improved heating and ventilation systems is seen to offset the negative net present value.

Without the schools, the total flow to the buildings considered is:

40°C water = 10.1 L/s

55°C water = 7.8 L/s

80°C water = 6.1 L/s

With the use of 55°C water, a number of additional buildings could and should be added to the system to bring the total flow up to the total anticipated maximum flow of 10 L/s. Without the added buildings, the billing rate for water would have to increase to recover the initial and operating costs. (For 55°C water, the rate would have to increase by 28% to recover all costs without the addition of other buildings. Even with the 28% increase, all buildings will still have a positive net present value.)

This study was limited to the most likely applications however there may be other buildings which can use geothermal heat beneficially. Where other owners wish to consider the use of geothermal heat, their decision criteria should be to proceed if they have a positive net present value.

The Benefit/Cost ratios can be used to gain the most benefit from a geothermal system. For example, for 55°C water, the typical home has a benefit/cost ratio of 1.4 which is greater than that of City Hall, the Library, the Museum, B.C. Fruit Packers and the R.C.M.P. Station. It would be beneficial if many homeowners and retail stores connected to the system even to the point of eliminating the above buildings because of the maximum flow constraint of the well. The net effect of this would be to increase the benefit of the investment to the community.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The prospect of obtaining heat energy from a natural hot water source may be appealing from both an environmental and asthetic standpoint, however development of geothermal energy should be given due economic consideration. In order to assess the feasibility of geothermal resources, the risks involved in geothermal exploration, thermal fluid distribution and conversion costs, and environmental and public acceptability issues must be weighed against the current and future costs of conventional energy sources. While development is possible from a technological standpoint, it is these economic considerations that will crucially affect the utilization of geothermal resources.

Based on current geological evidence, there appears to be a good likelihood of encountering heated groundwaters at temperatures between 50°C and 65°C from depths on the order of 1000 m beneath the town of Summerland. Preliminary analysis of the hydrogeological characteristics of the Summerland basin sediments indicates that a geothermal well could produce groundwater at a rate between 3 and 10 L/s.

Thermal waters may be encountered at shallower depths in the vicinity of the Summerland fault (the hypothesized "discharge area" for the Summerland basin). However, at this early stage in the investigation of the resource, and for the current lack of appropriate applications sites in this locality, development should be focussed on areas where the energy may be utilized by several larger, centralized consumers who would be capable of offsetting exploration and production expenses against potential energy cost savings.

Despite a relatively limited knowledge of geological conditions within the Summerland basin, the hypothesized depth and relatively low temperature of these resources indicate that deep exploration drilling will be required in order to significantly advance geothermal development, and that only a single well production scenario would prove economic. Furthermore, the only cost-effective deep drilling technique is one which will permit production of thermal fluids; specifically, one in which the well bore will accomodate a downhole pump. Because drilling conditions within the basin are virtually unknown, the equipment selected must have the versatility to withstand any number of factors potentially detrimental to a successful program.

Based on a survey of drilling industry contractors and suppliers, it is evident that specialized water well equipment will be required in order to provide the most cost-effective exploration and production options for a geothermal demonstration project. At \$250,000 the estimated cost of completing a 160 mm well bore to 1000 m using a water-well rotary rig is approximately 60% of a comparable program using oilfield rotary equipment. The depth of the "dynamic water level" will have a significant impact on both drilling and completion costs and upon production options and capacity. While the costs of a diamond drilling program compare very favourably with other options, the likelihood of a shallow well abandonment because of insurmountable drilling difficulties, and the extremely limited production capability of the small diameter bore make the technique the least cost effective.

It has been assumed that surface disposal of exhausted fluids will be possible. Should chemical analyses of the thermal water indicate that this technique is inappropriate, it may be necessary to implement such costly alternatives as chemical treatment or re-injection. The latter would require the drilling of a disposal well and could have considerable impact on the project's economics. The scaling

characteristics of the fluid will also affect equipment selection and disposal options. While no data is available for Summerland waters, the nature of thermal fluids collected from a nearby basin with a similar geological environment indicates that neither scaling nor toxicity characteristics should pose a problem for geothermal resource development.

Two general applications in the Summerland vicinity are particularly amenable to conversion to geothermal heating. Prime candidates for a geothermal demonstration project would be either Mountain View Farms' greenhouse facility or a small scale district heating scheme involving, primarily, public buildings within the downtown area.

Designed to totally heat the buildings down to 0°C (and thereby providing approximately 90% of annual heating demands), economic analysis of the greenhouse system indicates attractive benefit/cost ratios for applications using water at and above the anticipated delivery temperature. Even for a "pessimistic scenario" where geothermal resources of 40°C are encountered, the analysis shows positive net present values. Provided that the drilling program results in a geothermal "discovery" and that the indicated assumptions hold true, implementation of a geothermal greenhouse system appears to be a good investment. The greenhouse application heat would however, be limited to the heating demand of the specific greenhouse facility.

The district heating system scenario was designed and costed using several centrally located energy consumers in the downtown area. The Aquatic Centre is the principal candidate with a relatively high heat demand year-round, and a heating and ventilation system readily adaptable to inclusion of a geothermal energy source. In contrast,

analysis of both the High School and MacDonald Elementary School indicate that conversion to geothermal heating would be uneconomic for these candidates primarily because of the expense of retrofitting the buildings with modern heating equipment.

Should exploration prove successful, the utilization of geothermal resources for building heating appears to be economically favourable under the criteria used in our model. With the exception of the schools and the fruit packing plant, the net present value of a geothermal conversion is positive under all the resource scenarios considered. At the expected delivery temperatures of 55°C and above, benefit/cost ratios support the replacement of conventional energy sources with geothermal alternatives.

The benefit/cost ratios are highest for the central district heating scenario due primarily to its ability to make more efficient use of the available heat. However, the greenhouse has a significantly lower first cost than does the central heating system (\$409,000 for the greenhouse and \$554,000 for a central system serving all buildings considered except the schools). For this reason the former application may be more attractive as a demonstration project. The nature and source of funding will ultimately determine which of the two applications would be selected for geothermal utilization.

6.2 Recommendations

Given that installation of heating systems utilizing the geothermal resources thought to be present beneath Summerland appears to be practically and economically feasible, exploration for the resource should proceed. However, information on geological conditions deep within the Basin is very limited, and investigation of Summerland's

geothermal resources is at a high risk stage. Considerable expenditures will be required in order to make an assessment of the size and nature of the geothermal resource, or indeed, if the resource is present at all.

Accordingly, exploration should have as its main objectives:

1. to provide geological and geotechnical data vital to the evaluation of the geothermal resource, and
2. to permit utilization of the resources in at least a demonstration capacity.

Deep exploration drilling using water well equipment is the most cost-effective technique for achieving these objectives. Because large initial capital outlays for development of low temperature geothermal resources would mitigate their competitive advantage over conventional energy sources, the use of other exploration options, particularly those which would not facilitate delivery of the thermal fluids to surface, should be discouraged. The well would be drilled just south of the Aquatic Centre or at a point central to the greenhouse facility, depending on the application selected for demonstration.

As it becomes available, geological and engineering data on the geothermal resource including parameters such as temperature, pressure, permeability, and geochemistry must be evaluated. It is essential that geotechnical, engineering and economic models be adjusted as necessary to reflect the addition of new, more accurate information. At that time, a final decision regarding continuation of the project would be made.



REFERENCES

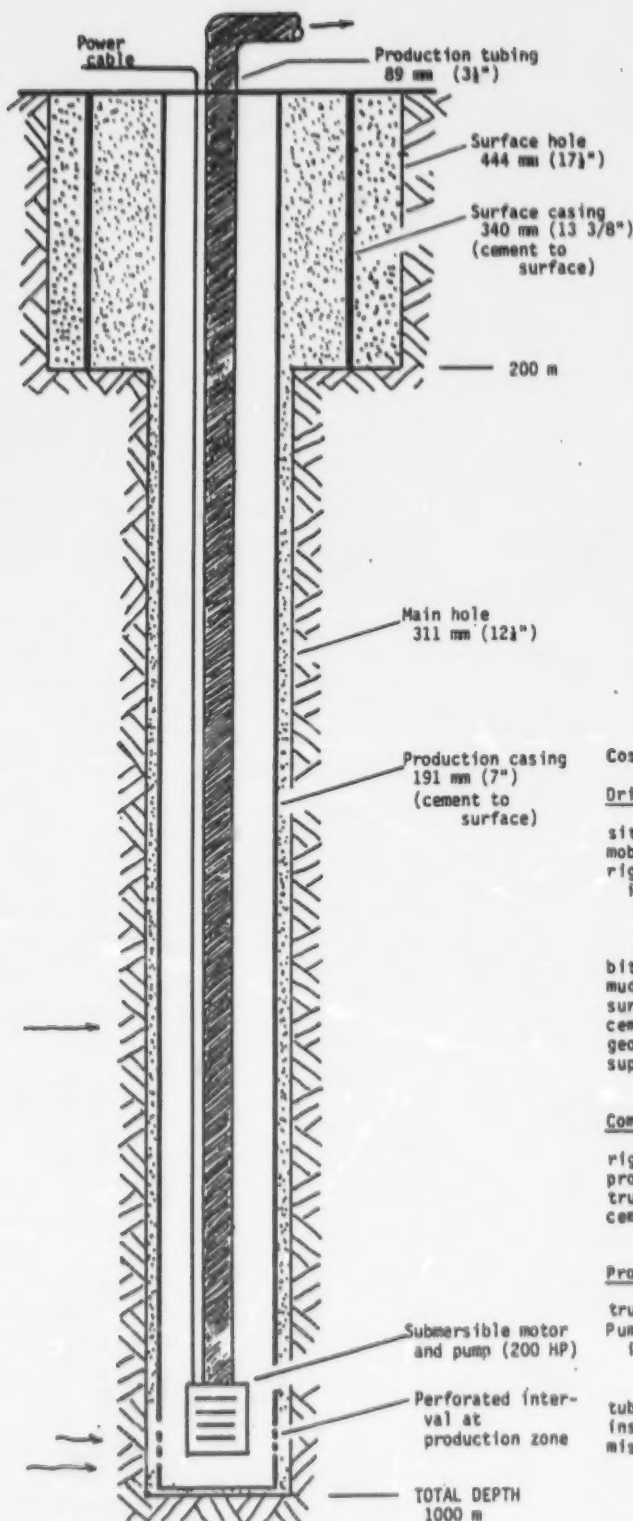
- Church, B.N. 1973. Geology of the White Lake basin. B.C. Department of Mines and Petroleum Resources, Victoria, B.C. Bulletin 61.
- _____. 1979a. Geology of the Penticton Tertiary outlier. B.C. Department of Energy, Mines and Petroleum Resources, Victoria, B.C. Preliminary Map 35.
- _____. 1979b. Tertiary stratigraphy and resource potential in south-central British Columbia. In Geological Fieldwork 1979. British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Branch, Paper 79-1, pp. 7-15.
- _____. 1980a. Geology of the Kelowna Tertiary outlier (west half 82 E/13). Mineral Resources Division, Geological Branch, B.C. Ministry of Energy, Mines and Petroleum Resources. Preliminary Map 39.
- _____. 1980b. Anomalous Uranium in the Summerland Caldera. In Geological Fieldwork 1979. B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Branch, Paper 1980-1, pp. 11-15.
- _____. 1982. Notes on the Penticton Group. A progress report on a new stratigraphic subdivision of the Tertiary in south-central British Columbia. In Geological Fieldwork 1981. B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Branch, Paper 82-1, pp. 12-16.
- Church, B.N., Ewing, T.E. and Hora, Z.D. 1983. Volcanology, structure, coal and mineral resources of early Tertiary outliers in south-central British Columbia. Geological Association of Canada, Joint Annual Meeting, Field Trip No. 1, 91 p.
- Davis, E.E. and Lewis, T.J. 1984. Heat flow in a back-arc environment: Intermontane and Omineca Crystalline belts, southern Canadian Cordillera. Canadian Journal of Earth Sciences, 20, No. 6, pp. 715-726.
- Grant, M.B. and Michel, F.A. 1985. Study of the hydrogeology of the White Lake basin, British Columbia. Earth Physics Branch, Ottawa, Ont. Open File 85-28.

- Jessop, A.M. and Judge, A.S. 1971. Five measurements of heat flow in southern Canada. Canadian Journal of Earth Sciences 8, No. 6, pp. 711-716.
- Lewis, T.J. 1984. Geothermal energy from Penticton Tertiary outlier, British Columbia: an initial assessment. Canadian Journal of Earth Sciences, 21, pp. 181-188.
- Lewis, T.J. and Werner, L. 1982. Geothermal gradients on the west side of Okanagan Lake, B.C. Earth Physics Branch, Ottawa, Ont. Open File 82-6.
- D.R. Piteau & Assoc. 1984. Summerland Basin hydrogeological study. Earth Physics Branch, Ottawa, Ont. Open File 85-29.
- Sproule Associates Limited 1984. Design and costs for possible geothermal test well, Summerland Basin, British Columbia. Open Filed report to Energy, Mines and Resources Canada.
- J.E. Sworder Engineering Ltd. 1984. Geothermal Heat Project. (Brief analysis of heating loads at Summerland B.C.). Open Filed correspondence with Earth Physics Branch, Energy Mines and Resources Canada.

APPENDIX A

Preliminary design and costing of
four geothermal well scenarios
for drilling in the
Summerland basin.

OPTION 1



Description:

Oilfield rotary well

Equipment:

Standard oilfield rotary drilling rig equipped with "double" derrick (allowing two lengths of drillpipe to be stacked at once).

Pump:

(As shown) 200 H.P. submersible at 1000 m.

Assumptions:

Worst case - as shown - Thermal water does not rise within well bore and pumping is required from 1000 m.

Best case - artesian flow - A large portion of "Production" costs are alleviated (i.e. pump, motor, tubing, cable).

Risks:

Unforeseeable geological complications to drilling could delay the program resulting in potentially large cost overruns in sensitive areas such as "rig charges". Also, because this scale of drilling equipment is not available locally, it has been necessary to include a large transportation allowance for move/demob from Alberta supply centers to Summerland.

The high costs of this drilling option may be justified in view of the high "reliability" of the technique (i.e. drilling problems are more capably handled by the large rotary equipment). However, the costs must be balanced against the likelihood that the well will be "dry", a strong possibility at this early stage in the investigation of this resource.

Costs:

Drilling

site preparation/clean-up	\$10,000
move/demob	80,000
rig charges	114,000
including:	
- drilling rig and equipment	
- crew - living allowance	
- water - fuel	
bits	20,000
mud and chemicals	5,000
surface casing (incl. trucking)	23,000
cementing	15,000
geophysical logging and testing	15,000
supervision and engineering	20,000
	<u>\$302,000</u>

Completion

rig charge	\$6,000
production casing	37,000
trucking	2,000
cementing	8,000
	<u>\$ 53,000</u>

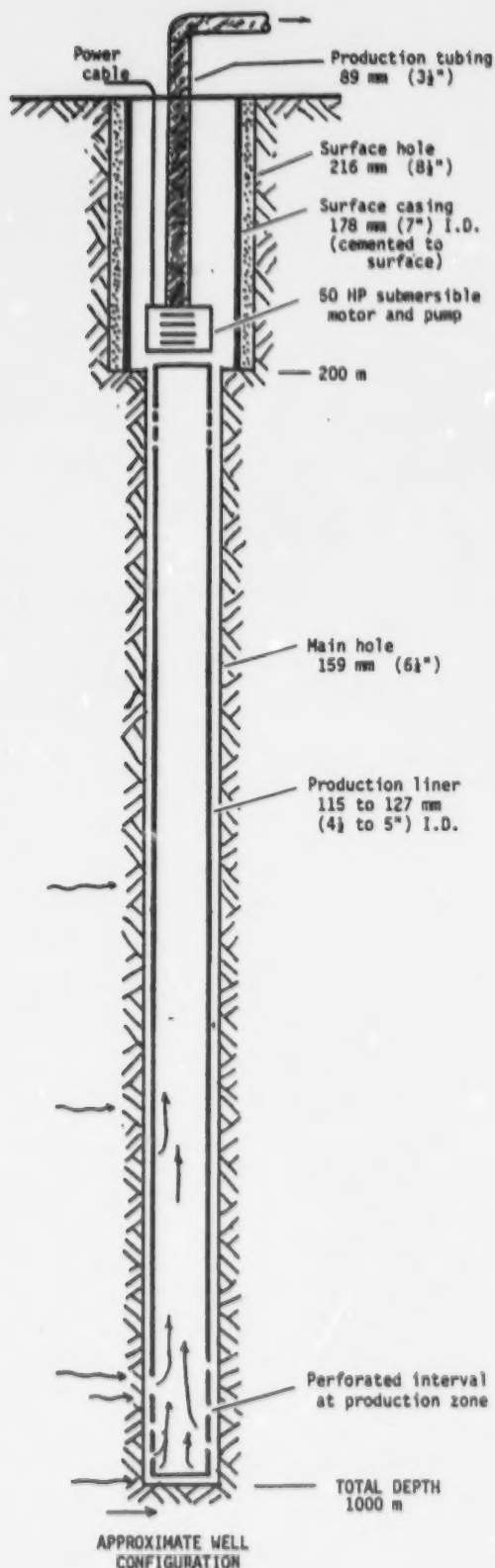
Production

trucking	\$ 3,000
Pump	55,000
including	
- motor - cable	
- wellhead	
tubing	10,000
installation	3,000
misc.	5,000
	<u>\$ 76,000</u>

TOTAL Option 1 \$431,000

APPROXIMATE WELL
CONFIGURATION

OPTION 2(a)



Description:

Deep, smaller diameter rotary well

Equipment:

Deep water well drilling rig ("Fayling") equipped to drill to 1100 m.

Pump:

50 H.P. submersible at 150 to 200 m.

Assumptions:

Dynamic water level (that level maintained within the well bore under pumping conditions) will be at 150 to 200 m. If smaller production volumes are acceptable, the pump could be set deeper for approximately the same cost.

Comments:

Unforeseeable geological complications to drilling could delay, or possibly jeopardize the drilling program. While "rig charges" are somewhat lower than those in Option 1, cost overruns resulting from drilling delays may be significant. Again, this scale of drilling equipment is not available locally, and it has been necessary to include a large transportation allowance for move/demob from Alberta supply centers to Summerland.

Cost savings of this Option over Option 1 are balanced by the increased risks involved in drilling with equipment approaching its depth limitations. Accordingly, fewer options are available to the contractor should drilling difficulties be encountered. Again, the cost benefits of Option 2(a) must be balanced against the likelihood that the well will be "dry", a strong possibility at this early stage in the investigation of this resource.

Costs:

Drilling

site preparation/clean-up	\$10,000	
move/demob	66,000	
rig charges	54,000	
including:		
- drilling rig and equipment		
- crew - living allowance		
- water - fuel		
bits	7,000	
air compressors	12,000	
surface casing (incl. trucking)	5,500	
cementing	10,000	
geophysical logging and testing	10,000	
supervision and engineering	15,000	
		\$189,500

Completion

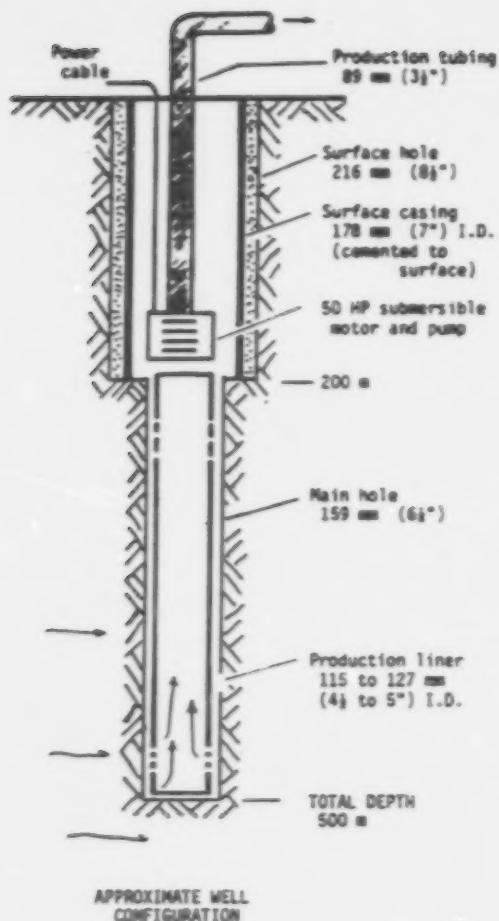
rig charge	\$5,000	
production casing	21,000	
trucking	2,000	
		\$ 28,000

Production

Pump	\$25,000	
including		
- motor		
- tubing		
- thrust chamber		
Installation	3,000	
		\$ 28,000

TOTAL Option 2(a) \$245,500

OPTION 2(b)



Description:

Shortened version of Option 2(a) using deep, smaller diameter rotary well.

Equipment:

Deep water well drilling rig ("Tayling") equipped to drill to 1100 m.

Pump:

50 H.P. submersible at 150 to 200 m.

Assumptions:

Geothermal waters of sufficient (greater than 40°C) temperature are located nearer surface. Dynamic water level (that level maintained within the well bore under pumping conditions) will be at 150 to 200 m. If smaller production volumes are acceptable, the pump could be set deeper for approximately the same cost.

Comments:

This scenario was developed to demonstrate the effect upon development costs if geothermal resources were encountered at considerably shallower depth than currently envisioned. While geological complications to drilling could still delay, or possibly jeopardize the program, the chances that a shallower hole would be successfully completed are substantially higher. The scenario presumes that Option 2(a) intersects "economic" temperatures well before the 1000 m target depth and that a decision to terminate drilling is made at that point. The potential for higher temperatures at greater depth under a "drill ahead" decision must be balanced against the possibility of "losing the hole".

It is also conceivable that smaller, locally available equipment could be utilized to drill to a 500 m target depth at substantial cost savings. However, the likelihood of identifying geothermal resources at the application sites under consideration at this comparatively shallow depth appears limited.

Costs:

Drilling

site preparation/clean-up	\$10,000	
move/demove	66,000	
rig charges	35,000 *	
including:		
- drilling rig and equipment		
- crew - living allowance		
- water - fuel		
bits	\$ 4,000 *	
air compressors	7,500 *	
surface casing (incl. trucking)	5,500	
cementing	10,000	
geophysical logging and testing	10,000	
supervision and engineering	12,000	
		\$160,000

Completion

rig charge	\$3,000	
production casing	9,000 *	
trucking	1,500	
		\$ 13,500

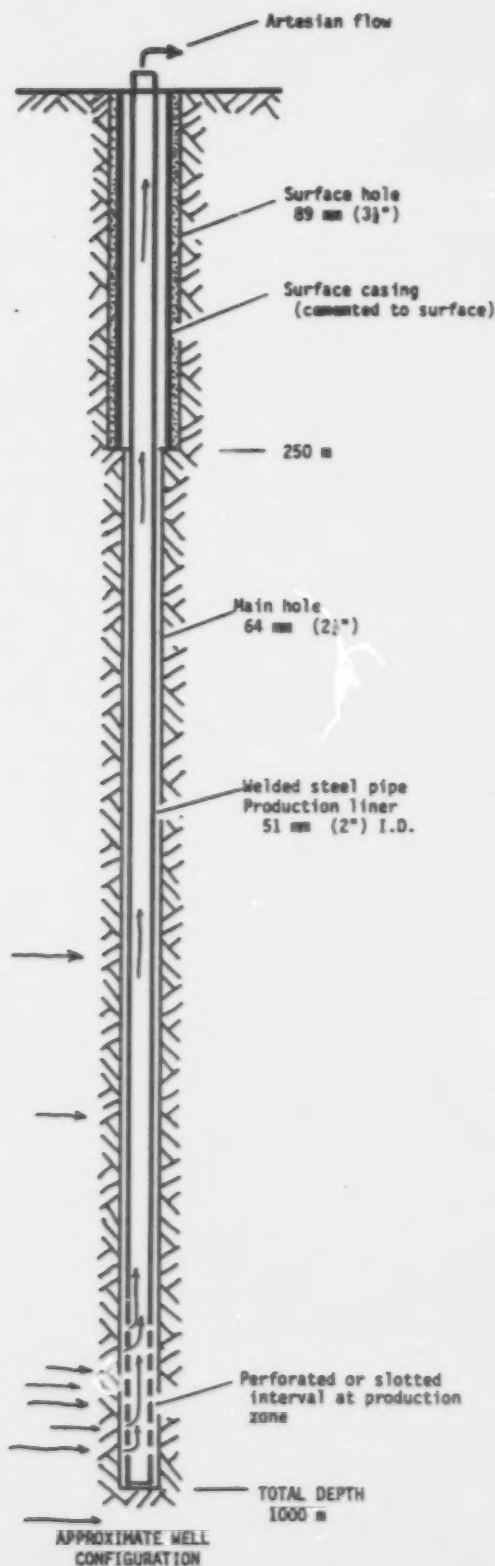
Production

Pump	\$25,000	
including		
- motor - cable		
- tubing - wellhead		
- thrust chamber		
installation	3,000	
		\$ 28,000

TOTAL Option 2(b) \$201,500

* - significant reductions over Option 2(a)

OPTION 3



Description:

Diamond drill hole cased with 5 cm liner.

Equipment:

Longyear 44 or equivalent diamond drill rig using HQ and NQ equipment.

Pump:

Because of the small diameter of the casing, a downhole pump delivering the required flow cannot be accommodated.

Assumptions:

Artesian flow conditions are essential. It is unlikely that thermal fluids under the pressure conditions required to deliver 3 to 10 L/s would be encountered beneath the application sites under consideration.

Comments:

While diamond drilling is the least expensive option, and provides the best geological record, the nature of the resource envisioned and the tight constraints on potential application sites are likely to render this technique impractical. Because of the nature of the Basin sediments, conditions which might not deter other drilling techniques might force the abandonment of a diamond drilling program, making the probability of successful completion unacceptably low. Furthermore, unless high pressure flowing conditions are encountered, the slim diameter of the well bore precludes any substantial fluid production from a cased diamond drill hole.

Costs:

Drilling

site preparation/clean-up	\$ 7,000	
mobe/demobe	8,000	
rig charges:		
HQ (89 mm hole) to 150 m	25,000	
NQ (64 mm hole) 150 to 1000 m	71,000	
surface casing/cementing	7,500	
geophysical logging and testing	10,000	
supervision and engineering	15,000	
		\$143,500

Completion

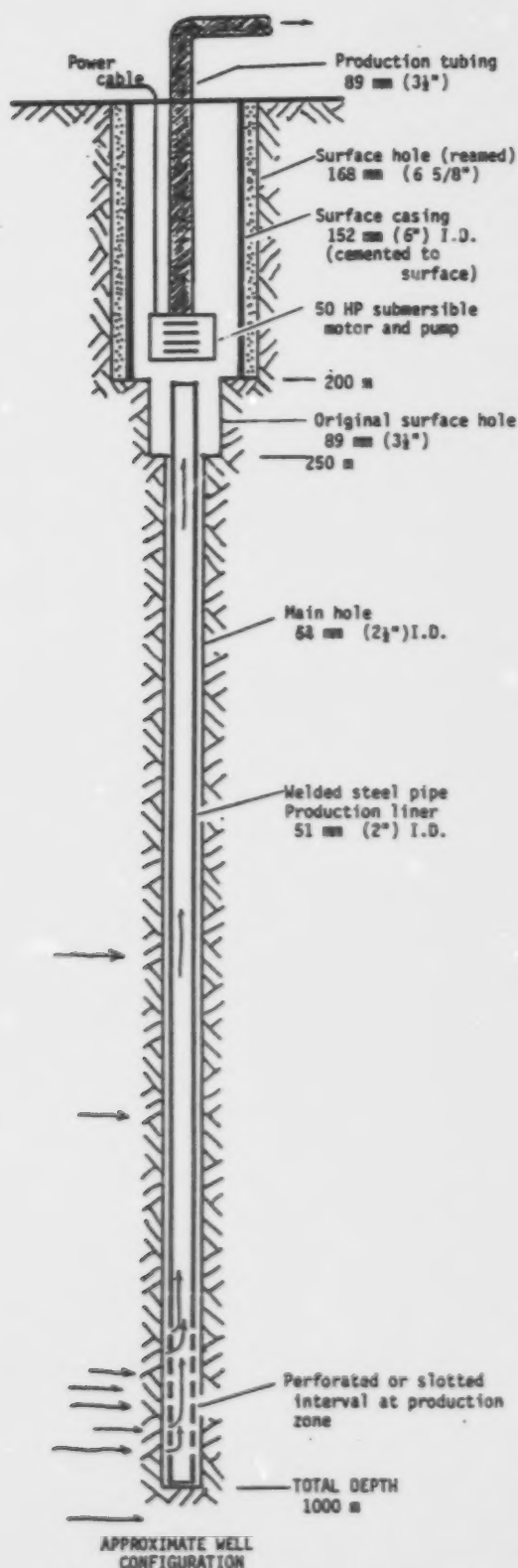
rig charge	\$2,000	
production casing	18,000	
welder	1,500	
trucking	1,500	
		\$ 23,000

Production

wellhead	\$2,000	
(production other than by artesian flow is impractical.)		\$ 2,000

TOTAL Option 3 \$168,500

OPTION 4(a)



Description:

Diamond drill hole to 1000 m reamed to 168 mm (6 5/8") by rotary water well.

Equipment:

Longyear 44 or equivalent diamond drill equipment (as in Option 3) with pilot hole reamed out with conventional water well drill.

Pump:

50 H.P. submersible at 150 to 200 m.

Assumptions:

Sufficient resource temperature and permeabilities are encountered during a diamond drilling program to justify increasing the size of the bore to a depth of 150 to 200 m in order to accommodate a downhole pump. Because of the narrow diameter of the diamond drilled section of the hole, a practical maximum production rate through a 50 mm liner is 2 to 3 L/s. Dynamic water level (that level maintained within the well bore under pumping conditions) will be at 150 to 200 m. This scenario is viable only if smaller production volumes are acceptable.

Comments:

This scenario was developed in order to evaluate the practicality of reaming out a diamond drill hole successfully completed at a geothermal "discovery zone" at 1000 m. In effect, it is an extension of Option 3, and certainly would not be undertaken unless the diamond drilling program indicated that installation of a downhole pump would greatly augment the productivity of the well. With the exception of technical difficulties arising from possible plugging of the pilot diamond drill hole, reaming could be conducted without geological risk. Casing and cementing would require some innovative techniques and accordingly, successful completion could be placed at risk.

This technique would be employed only if a large number of rather demanding geological constraints could be satisfied.

Costs:

Drilling

site preparation/clean-up	\$ 7,000	
mobe/demobe	8,000	
rig charges	96,000	
(as in Option 3)		
geophysical logging and testing	10,000	
supervision and engineering	15,000	
misc. preparation for reaming	5,000	
		\$141,000

Reaming

footage (200 m @ \$72)	\$14,500	
mobe/demobe	3,000	
		\$ 17,500

Completion

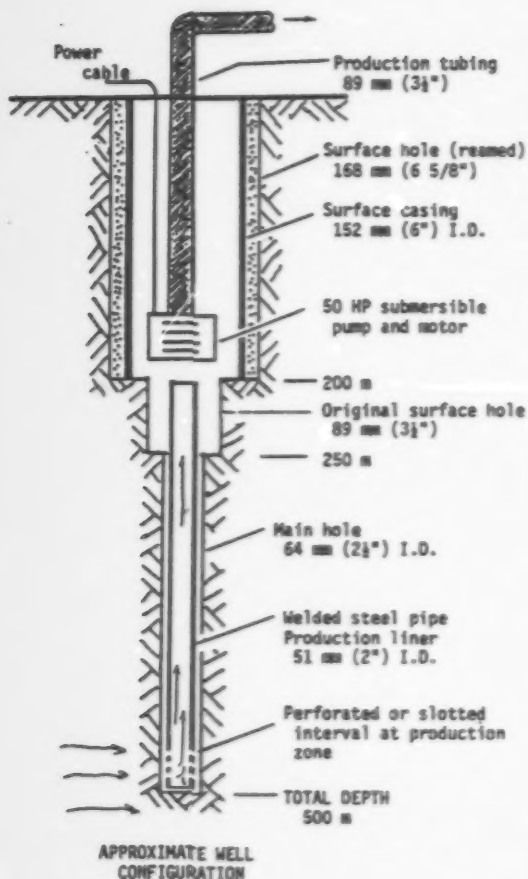
rig charge	\$3,000	
production casing	20,000	
cementing	8,000	
trucking	5,000	
		\$ 36,000

Production

Pump	\$27,000	
including		
- motor	- cable	
- tubing	- wellhead	
- thrust chamber		
Installation	3,000	
		\$ 30,000

TOTAL Option 4(a) \$224,500

OPTION 4(b)



Description:

Diamond drill hole to 500 m reamed to 168 mm (6 5/8") by rotary water well. Same as Option 4(a) except in length of diamond drill hole.

Equipment:

Longyear 44 or equivalent diamond drill equipment (as in Option 3) with pilot hole reamed out with conventional water well drill.

Pump:

50 H.P. submersible at 150 to 200 m.

Assumptions:

Same as Option 4(a).

Comments:

This scenario was developed to demonstrate the effect of a shallower discovery while constrained by the conditions in Option 4(a); that is, a diamond drill completion (though at only 500 m), and insufficient formation pressures to produce an artesian flow. Again, geological conditions would have to be nearly ideal in order to warrant the risks involved in reaming the hole. Option 2(b) would be a more plausible production technique if "shallow" geothermal resources are encountered in exploration diamond drilling.

Costs:

Drilling

site preparation/clean-up	\$ 7,000
mobe/demobe	8,000
rig charges	38,000
(modified from Option 3)	
geophysical logging and testing	4,000
supervision and engineering	9,000
misc. preparation for reaming	2,000
	<u>\$ 68,000</u>

Reaming

footage (200 m @ \$72)	14,500
mobe/demobe	3,000
	<u>\$ 17,500</u>

Completion

rig charge	\$3,000
production casing	11,000
cementing	7,000
trucking	5,000
	<u>\$ 26,000</u>

Production

Pump	\$27,000
including	
- motor	- cable
- tubing	- wellhead
- thrust chamber	
installation	3,000
	<u>\$ 30,000</u>

TOTAL Option 4(b) 141,500

APPENDIX . B

Installation Cost Estimates
for
District Geothermal Heating System candidates

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: AQUATIC CENTRE

System Type: Coil Retrofit,

Domestic Hot Water Heat Exchanger

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Coils	\$ 2,300.	\$ 1,600.	\$ 1,600.
Pool Heating Heat Exchanger	\$ 1,000.	\$ 700.	\$ 700.
Domestic Water Heat Exchanger	\$ 1,000.	\$ 700.	\$ 700.
Domestic Water Storage Tank	\$ 2,200.	\$ 2,200.	\$ 2,200.
Pump	\$ 600.	\$ 600.	\$ 600.
Piping	\$ 1,300.	\$ 1,300.	\$ 1,300.
Valves	\$ 300.	\$ 300.	\$ 300.
Controls	\$ 2,600.	\$ 2,600.	\$ 2,600.
Electrical	\$ 300.	\$ 300.	\$ 300.
Service	\$ 1,300.	\$ 1,300.	\$ 1,300.
Sub Total	\$ 12,900.	\$ 11,600.	\$ 11,600.
Contingency	\$ 2,100.	\$ 1,400.	\$ 1,400.
Total	\$ 15,000.	\$ 13,000.	\$ 13,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: CITY HALL

System Type: Heat Pump

Item	Geothermal
	Water Temperature 40°C.
Heat Pump Units	\$ 13,400.
Pump	\$ 500.
Piping	\$ 2,600.
Valves	\$ 200.
Controls	\$ 100.
Electrical	\$ 1,400.
Ductwork	\$ 4,000.
Service	\$ 800.
Sub Total	\$ 23,000.
Contingency	\$ 4,000.
Total	\$ 27,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: CITY HALL

System Type: Fan Coil Units

Item	Geothermal Water Temperature	
	55°C.	80°C.
Fan Coil Units	\$ 18,000.	\$ 9,600.
Piping	\$ 5,900.	\$ 4,700.
Valves	\$ 900.	\$ 500.
Controls	\$ 3,000.	\$ 1,900.
Electrical	\$ 1,900.	\$ 1,100.
Service	\$ 800.	\$ 800.
Sub Total	\$ 30,500.	\$ 18,600.
Contingency	\$ 5,500.	\$ 3,400.
Total	\$ 36,000.	\$ 22,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: CITY HALL

System Type: Baseboard Radiators

Item	Geothermal
	Water Temperature 80°C.
Baseboard Heaters	\$ 4,000.
Piping	\$ 3,000.
Valves	\$ 500.
Controls	\$ 1,900.
Service	\$ 800.
Sub Total	\$ 10,200.
Contingency	\$ 1,800.
Total	\$ 12,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: LIBRARY

System Type: Coil Retrofit,

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Coils	\$ 2,000.	\$ 1,500.	\$ 1,500.
Pump	\$ 600.	\$	\$
Piping	\$ 800.	\$ 700.	\$ 700.
Valves	\$ 100.	\$ 100.	\$ 100.
Controls	\$ 200.	\$ 200.	\$ 200.
Electrical	\$ 300.	\$	\$
Service	\$ 700.	\$ 700.	\$ 700.
Sub Total	\$ 4,700.	\$ 3,200.	\$ 3,200.
Contingency	\$ 700.	\$ 500.	\$ 500.
Total	\$ 5,400.	\$ 3,700.	\$ 3,700.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: MUSEUM

System Type: Coil Retrofit,

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Coils	\$ 1,600.	\$ 1,600.	\$ 1,200.
Piping	\$ 900.	\$ 900.	\$ 900.
Valves	\$ 100.	\$ 100.	\$ 100.
Controls	\$ 300.	\$ 300.	\$ 300.
Service	\$ 1,600.	\$ 1,600.	\$ 1,600.
Sub Total	\$ 4,500.	\$ 4,500.	\$ 4,100.
Contingency	\$ 700.	\$ 700.	\$ 700.
Total	\$ 5,200.	\$ 5,200.	\$ 4,800.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: HIGH SCHOOL

System Type: Unit Ventilators

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Unit Ventilators	\$234,000.	\$234,000.	\$217,000.
Pumps	\$ 1,000.	\$ 1,000.	\$ 1,000.
Piping *	\$ 63,000.	\$ 60,000.	\$ 72,000.
Valves	\$ 4,000.	\$ 4,000.	\$ 4,000.
Controls	\$ 7,000.	\$ 7,000.	\$ 7,000.
Electrical	\$ 11,000.	\$ 11,000.	\$ 11,000.
Service	\$ 10,000.	\$ 10,000.	\$ 10,000.
Sub Total	\$330,000.	\$327,000.	\$322,000.
Contingency	\$ 48,000.	\$ 48,000.	\$ 47,000.
Total	\$378,000.	\$375,000.	\$369,000.

* Return piping uninsulated except for 80°C water return.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: HIGH SCHOOL

System Type: Heat Pump Unit Ventilators

Item	Geothermal
	Water Temperature 40°C.
Heat Pump Unit Ventilators	
incl. controls	\$340,000.
Pump	\$ 4,000.
Piping	\$ 58,000.
Valves	\$ 4,000.
Electrical	\$ 19,000.
Service	\$ 10,000.
Sub Total	\$435,000.
Contingency	\$ 64,000.
Total	\$499,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: HIGH SCHOOL

System Type: Ceiling Mounted Heat Pump Units

Item	Geothermal
	Water Temperature 40°C.
Heat Pump Units incl. controls	\$107,000.
Pumps	\$ 4,000.
Piping	\$ 58,000.
Valves	\$ 4,000.
Electrical	\$ 19,000.
Ductwork	\$ 54,000.
Service	\$ 10,000.
Sub Total	\$256,000.
Contingency	\$ 37,000.
Total	\$293,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: HIGH SCHOOL

System Type: Convector Cabinet Retrofit

Item	Geothermal
	Water Temperature 80°C.
Convector Cabinets	\$110,000.
Pump	\$ 1,000.
Piping	\$ 81,000.
Valves	\$ 4,000.
Controls	\$ 8,000.
Electrical	\$ 1,000.
Service	\$ 10,000.
Sub Total	\$215,000.
Contingency	\$ 30,000.
Total	\$245,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: ELEMENTARY SCHOOL

System Type: Unit Ventilators & Coil Retrofit

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Unit Ventilators	\$ 67,000.	\$ 67,000.	\$ 62,000.
Coils	\$ 5,000.	\$ 5,000.	\$ 5,000.
Pump	\$ 1,000.	\$ 1,000.	\$ 1,000.
Piping *	\$ 35,000.	\$ 32,000.	\$ 41,000.
Valves	\$ 2,000.	\$ 2,000.	\$ 2,000.
Controls	\$ 4,000.	\$ 4,000.	\$ 4,000.
Electrical	\$ 7,000.	\$ 7,000.	\$ 7,000.
Service	\$ 2,000.	\$ 2,000.	\$ 2,000.
Sub Total	\$123,000.	\$120,000.	\$124,000.
Contingency	\$ 18,000.	\$ 18,000.	\$ 18,000.
Total	\$141,000.	\$138,000.	\$142,000.

* Return piping uninsulated except for 80°C return.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: ELEMENTARY SCHOOL

System Type: Ceiling Mounted Heat Pumps & Coil Retrofit

Item	Geothermal
	Water Temperature 40°C.
Heat Pump Units incl. controls	\$ 31,000.
Coils	\$ 5,000.
Pump	\$ 4,000.
Piping	\$ 32,000.
Valves	\$ 3,000.
Electrical	\$ 11,000.
Ductwork	\$ 31,000.
Service	\$ 2,000.
Sub Total	\$119,000.
Contingency	\$ 18,000.
Total	\$137,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: ELEMENTARY SCHOOL

System Type: Convactor Cabinet Retrofit and Coil Retrofit

Item	Geothermal
	Water Temperature 80°C.
Convactor Cabinets	\$ 33,000.
Coils	\$ 4,000.
Pump	\$ 1,000.
Piping	\$ 47,000.
Valves	\$ 2,000.
Controls	\$ 2,000.
Electrical	\$ 1,000.
Service	\$ 2,000.
Sub Total	\$ 92,000.
Contingency	\$ 15,000.
Total	\$107,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: RECREATION CENTRE

System Type: Coil Retrofit;

Fan Coil Units; DHW Heat Exchanger

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Fan Coil Units	\$ 17,700.	\$ 14,200.	\$ 10,600.
Coils	\$ 2,800.	\$ 2,800.	\$ 2,800.
DHW Heat Exchanger	\$ 700.	\$ 700.	\$ 700.
DHW Storage Tank	\$ 1,800.	\$ 1,800.	\$ 1,800.
Pump	\$ 1,000.	\$ 700.	\$ 500.
DHW Pump	\$ 500.	\$ 500.	\$ 500.
Piping *	\$ 6,000.	\$ 4,500.	\$ 5,400.
Valves	\$ 600.	\$ 500.	\$ 500.
Controls	\$ 5,600.	\$ 4,900.	\$ 4,200.
Electrical	\$ 2,100.	\$ 1,800.	\$ 1,500.
Ductwork	\$ 11,000.	\$ 8,800.	\$ 6,600.
Service	\$ 1,000.	\$ 1,000.	\$ 1,000.
Sub Total	\$ 50,800.	\$ 42,200.	\$ 36,100.
Contingency	\$ 9,200.	\$ 7,800.	\$ 6,900.
Total	\$ 60,000.	\$ 50,000.	\$ 43,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: B.C. FRUIT PACKERS

System Type: Fan Coil Units

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Fan Coil Units	\$ 58,300.	\$ 31,900.	\$ 31,900.
Pump	\$ 1,000.	\$ 700.	\$ 500.
Piping *	\$ 28,000.	\$ 27,000.	\$ 32,700.
Valves	\$ 1,400.	\$ 1,200.	\$ 1,000.
Controls	\$ 8,400.	\$ 6,300.	\$ 6,300.
Electrical	\$ 6,500.	\$ 5,000.	\$ 5,000.
Ductwork	\$ 3,600.	\$ 2,700.	\$ 2,700.
Service	\$ 4,000.	\$ 4,000.	\$ 4,000.
Sub Total	\$111,200.	\$ 78,800.	\$ 84,100.
Contingency	\$ 16,800.	\$ 11,200.	\$ 11,900.
Total	\$128,000.	\$ 90,000.	\$ 96,000.

* Return piping uninsulated except for 80°C water.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: B.C. FRUIT PACKERS

System Type: Heat Pump Units

Item	Geothermal
	Water Temperature 40°C.
Heat Pump Units including Controls	\$ 66,000.
Pump	\$ 500.
Piping	\$ 20,300.
Valves	\$ 1,800.
Electrical	\$ 10,000.
Service	\$ 4,000.
Sub Total	\$102,600.
Contingency	\$ 15,400.
Total	\$118,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: R.C.M.P. Station

System Type: Coil Retrofit

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Coils	\$ 2,700.	\$ 2,200.	\$ 2,100.
Pump	\$ 500.	\$ 500.	\$ 500.
Piping	\$ 1,400.	\$ 1,400.	\$ 1,300.
Valves	\$ 200.	\$ 200.	\$ 200.
Controls	\$ 500.	\$ 500.	\$ 500.
Electrical	\$ 300.	\$ 300.	\$ 300.
Service	\$ 1,300.	\$ 1,300.	\$ 1,300.
Sub Total	\$ 6,900.	\$ 6,400.	\$ 6,200.
Contingency	\$ 1,100.	\$ 1,000.	\$ 900.
Total	\$ 8,000.	\$ 7,400.	\$ 7,100.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: Typical Residence

System Type: Coil Retrofit

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Coils	\$ 700.	\$ 500.	\$ 500.
Piping	\$ 500.	\$ 500.	\$ 500.
Valves	\$ 100.	\$ 100.	\$ 100.
Controls	\$ 100.	\$ 100.	\$ 100.
Service	\$ 1,000.	\$ 1,000.	\$ 1,000.
Sub Total	\$ 2,400.	\$ 2,200.	\$ 2,200.
Contingency	\$ 300.	\$ 300.	\$ 300.
Total	\$ 2,700.	\$ 2,500.	\$ 2,500.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: MOUNTAIN VIEW FARMS GREENHOUSES

System Type: Fan Coil System

Item	Geothermal Water Temperature		
	40°C.	55°C.	80°C.
Fan Coil Units	\$146,000.	\$106,000.	\$106,000.
Piping	\$ 25,000.	\$ 16,000.	\$ 16,000.
Valves	\$ 3,000.	\$ 2,000.	\$ 2,000.
Controls	\$ 6,000.	\$ 6,000.	\$ 6,000.
Electrical	\$ 10,000.	\$ 10,000.	\$ 10,000.
Pump House	\$ 2,000.	\$ 2,000.	\$ 2,000.
Sub Total	\$192,000.	\$142,000.	\$142,000.
Contingency	\$ 28,000.	\$ 21,000.	\$ 21,000.
Total	\$220,000.	\$163,000.	\$163,000.

Appendix B

SYSTEM INSTALLATION COST ESTIMATE

BUILDING: MOUNTAIN VIEW FARMS GREENHOUSE

System Type: Heat Pump Units

Item	Geothermal
	Water Temperature 40°C.
Heat Pumps	\$ 95,000.
Pump	\$ 3,000.
Piping	\$ 25,000.
Valves	\$ 4,000.
Controls	\$
Electrical	\$ 10,000.
Pumphouse	\$ 2,000.
Sub Total	\$139,000.
Contingency	\$ 21,000.
Total	\$160,000.